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UNITED STATES DEPARTMENT OF AGRICULTURE

In Cooperation with the
Washington Agricultural Experiment Station

DEPARTMENT BULLETIN No. 1235

Washington, D. C. ▼ November 28, 1924

LIFE HISTORY OF THE CODLING MOTH IN THE YAKIMA VALLEY OF WASHINGTON

By

E. J. NEWCOMER, Entomologist, and W. D. WHITCOMB, Assistant Entomologist,

Fruit Insect Investigations, Bureau of Entomology

CONTENTS

	Page
Introduction	1
The Yakima Valley	2
Definitions of Terms	4
Methods and Rearing Apparatus Employed in the Life-History Studies	4
The Insectary	6
Seasonal-History Studies of 1919	6
Codling Moth Band Studies of 1919	20
Seasonal-History Studies of 1920	22
Codling Moth Band Studies of 1920	35
Seasonal-History Studies of 1921	37
Codling Moth Band Studies of 1921	53
Variations in the Seasonal History of the Codling Moth in the Upper and Lower Yakima Valleys	55
Seasonal-History Studies at Wenatchee, Wash., 1915-1916	56
Miscellaneous Studies	58
Review of Seasonal History of the Codling Moth in 1919, 1920, and 1921	72
Summary	73

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CONTENTS.

	Page.
Introduction	1
The Yakima Valley	2
Definitions of terms	4
Methods and rearing apparatus employed in the life-history studies	4
The insectary	6
Seasonal-history studies of 1919	6
Codling moth band studies of 1919	20
Seasonal-history studies of 1920	22
Codling moth band studies of 1920	35
Seasonal-history studies of 1921	37
Codling moth band studies of 1921	53
Variations in the seasonal history of the codling moth in the upper and lower Yakima valleys	55
Seasonal-history studies at Wenatchee, Wash, 1915–16	56
Miscellaneous studies	58
Review of seasonal history of the codling moth in 1919, 1920, and 1921	72
Summary	73

INTRODUCTION.

The codling moth, *Carpocapsa pomonella* L., is the most serious insect pest with which the apple growers of Washington have to contend. Previous to 1915, little trouble had been experienced in controlling this pest, but in the years 1915 to 1918, inclusive, losses from wormy apples increased, more difficulty being experienced in the region about Yakima than in the other important apple-growing regions of the State. This led the Bureau of Entomology, United States Department of Agriculture, at the request of the department of agriculture of the State, to establish a field station at Yakima, in the spring of 1919, for the purpose of making a careful study of the codling moth in Washington.[2]

[1] With notes on the life history in the Wenatchee Valley of Washington.

[2] The work was done under the direction of Dr. A. L. Quaintance, in charge of Fruit Insect Investigations, Bureau of Entomology, in cooperation with the Washington Agricultural Experiment Station. The senior author was placed in immediate charge of the work at Yakima, and was assisted throughout the investigations by the junior author. During the summer of 1920, Miss Sadie E. Keen, now with the Bureau of Entomology, assisted temporarily with the life-history investigations. Valuable assistance and information were given at various times by members of the Washington State department of agriculture, particularly by those located at Yakima in the capacity of horticultural inspectors.

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THE YAKIMA VALLEY.

The Yakima Valley of Washington, in a broad sense, includes several valleys along the Yakima River on the east slope of the Cascade Mountains. These are situated in Kittitas, Yakima, and Benton Counties. The Kittitas Valley, about Ellensburg, has an elevation of about 1,500 feet, and little of it is devoted to fruit raising. Following down the river the next valley is the Selah Valley, only a few miles square, and below this is the upper Yakima Valley, with its tributary districts, the Naches Valley and the Tieton section. These are all intensively planted to fruit orchards, consisting mostly of apples, and the elevation varies from approximately 1,000 feet above sea level at Yakima to 2,000 feet at Tieton. Passing through a narrow gap in a range of hills below the city of Yakima, the river enters the lower Yakima Valley, which is much larger than the others. It is approximately 55 miles long, and varies in width from 2 to 25 miles. The high ground east of the Yakima River is devoted largely to orchards, while the area west of the river, which is almost wholly included in the Yakima Indian Reservation, is mostly given over to the raising of hay, grain, and other field crops, though there are some orchards.

Practically all of the cropped land in this naturally arid region is irrigated by means of water taken from the Yakima, Tieton, and Naches Rivers. According to the Yakima Commercial Club, there is a total of 240,000 acres of irrigated land in crops in the Yakima Valley, exclusive of the Kittitas Valley. Of this, approximately 50,000 acres are in fruit. The tree census of Washington State department of agriculture shows that in 1918 there were about 2,000,000 apple trees, 500,000 pear trees, and 500,000 other fruit trees in Yakima County.

The climate of the Yakima Valley is dry, with a normal annual rainfall of from 7 to 9 inches, the distribution of which is shown in Table 1. During the summer the daily range of temperature is relatively great, often being 30°, and sometimes more than 40° F. A considerable amount of wind is experienced during the spring and early summer, which is doubtless a factor in distributing the codling moth from one orchard to another. Table 1, taken from published data of the United States Weather Bureau, gives further details as to the weather during the years this investigation was in progress.

TABLE 1.—*Annual meteorological summary, Yakima, Wash.*

1919.

Month.	Temperature (°F.).								Precipitation (inches).			Number of days.				Prevailing direction of wind.
	Means.			Extremes.				Greatest daily range.	Total.	Greatest in 24 hours.	Total snowfall (unmelted).	Precipitation (0.01 inch or more).	Maximum temperature.		Minimum temperature.	
	Maximum.	Minimum.	Monthly.	Highest.	Date.	Lowest.	Date.						32° or below.	90° or above.	32° or below.	0° or below.	
January	39.4	20.9	30.2	60	22	4	[1] 4	36	1.00	0.41	4.3	8	10	0	28	0	NW.
February	45.0	25.9	35.4	56	28	16	[1] 2	29	.99	.33	6.8	12	0	0	28	0	NW.
March	59.1	31.8	45.4	75	29	24	[1] 3	44	.10	.05	T.	4	0	0	18	0	NW.
April	67.9	39.1	53.5	83	27	26	11	39	.38	.25	0	2	0	0	6	0	NW.
May	73.8	43.4	58.6	92	21	32	30	45	.58	.33	0	4	0	1	1	0	NW.
June	79.9	47.2	63.6	94	19	35	10	44	.04	.04	0	1	0	3	0	0	NW.
July	80.6	55.5	72.6	104	15	42	[1] 6	46	.03	.03	0	1	0	18	0	0	NW.
August	88.8	54.1	71.4	98	18	47	29	42	.08	.08	0	1	0	16	0	0	NW.
September	75.4	45.2	60.3	88	24	29	29	44	.69	.44	0	8	0	0	2	0	NW.
October	62.6	33.8	48.0	89	7	12	25	51	.12	.12	T.	1	0	0	12	0	NW.
November	47.2	28.3	37.8	62	[1] 17	7	27	34	.50	.26	2.3	6	2	0	22	0	NW.
December	28.1	13.8	21.0	47	24	−24	13	26	.99	.34	8.0	6	17	0	30	5	NE.
Year	62.3	36.6	49.8	104	Jul 15	−24	Dec. 13	51	5.50	.44	21.4	54	29	38	147	5	NW.

1920.

January	35.5	21.3	28.4	60	[1] 16	10	6	27	0.94	0.64	7.5	3	15	0	27	0	NW.
February	47.2	25.4	36.3	62	12	20	[1] 22	38	.04	.04	T.	1	0	0	28	0	NE.
March	58.2	29.6	43.9	68	12	16	17	42	.02	.02	T.	1	0	0	21	0	NW.
April	62.2	34.3	48.2	82	26	24	3	42	.53	.14	2.0	8	0	0	11	0	NW.
May	71.7	41.2	56.4	86	7	32	[1] 28	44	.39	.25	0	3	0	0	2	0	NW.
June	78.7	48.6	63.6	98	30	40	1	45	.33	.11	0	5	0	3	0	0	NW.
July	91.2	58.6	74.8	100	28	50	[1] 13	41	.25	.16	0	2	0	20	0	0	NW.
August	86.7	55.2	71.0	102	15	39	28	43	.44	.35	0	2	0	17	0	0	NW.
September	76.0	46.1	61.0	91	3	35	26	41	1.18	.32	0	6	0	3	0	0	NW.
October	62.4	37.2	49.8	78	4	26	20	33	.55	.30	0	4	0	0	10	0	NW.
November	49.4	28.8	39.1	59	7	14	10	35	1.35	.44	T.	7	0	0	25	0	W.
December	39.7	25.9	32.8	50	[1] 3	12	25	21	1.82	.34	9.8	10	3	0	29	0	NW.
Year	63.2	37.7	50.4	102	Aug. 15	10	Jan. 6	45	7.84	.64	19.3	52	18	43	153	0	NW.

1921.

January	38.9	22.4	30.6	54	14	9	[1] 6	30	1.52	0.35	15.1	11	6	0	28	0	NE.
February	43.9	27.3	35.6	61	11	15	21	32	.59	.22	5.5	8	0	0	21	0	NW.
March	57.2	32.7	45.0	70	31	26	[1] 14	40	.25	.12	T.	4	0	0	18	0	NW.
April	63.4	36.2	49.8	76	11	26	24	38	.35	.18	T.	3	0	0	8	0	NW.
May	75.9	44.5	60.2	90	24	30	11	44	.92	.83	0	4	0	1	1	0	NW.
June	82.7	51.2	67.0	94	23	38	14	40	.27	.10	0	5	0	2	0	0	NW.
July	88.5	53.5	71.0	98	31	42	3	42	T.	T.	0	0	0	17	0	0	NW.
August	88.6	54.9	71.8	100	13	41	24	41	.02	.02	0	1	0	15	0	0	SW.
September	73.7	42.5	58.1	82	27	31	12	40	.27	.26	0	2	0	0	2	0	NW.
October	68.4	37.3	52.8	83	10	30	23	46	.31	.22	0	3	0	0	5	0	NE.
November	47.8	26.0	36.9	68	6	6	23	35	2.33	.85	5.4	7	5	0	23	0	NW.
December	37.3	24.0	30.8	66	12	6	31	26	1.24	.49	9.9	9	11	0	22	0	NW.
Year	63.9	37.7	50.8	100	Aug. 13	6	Nov. 23	46	8.07	.85	55.9	57	22	35	128	0	NW

[1] Occurring on more than one day.

NOTE.—Precipitation includes rain and melted snow, hail, and sleet. "T" indicates trace of precipitation.

DEFINITIONS OF TERMS.

The terms used in describing the various stages of the codling moth are the same as those employed by other members of the Bureau of Entomology in previous life-history studies.

A "generation" begins with the egg stage and ends with the adult or moth, and may or may not be completed the same season it begins.

A "brood" includes the individuals of any one of these stages, such as eggs, larvæ, pupæ, or adults, and may be spoken of as "first brood," "second brood," etc., to designate the generation to which it belongs. "Spring brood" includes the individual pupæ or adults which come from the "wintering larvæ," the latter being all the individuals of all the generations of the preceding season which do not complete their development until spring.

The time of cocooning is spoken of as the "cocooning period," since it is a part of the larval period.

The "life cycle" of any generation is the time from the deposition of the egg to the emergence of the adult.

The "complete life cycle" includes the time from the deposition of the egg of one generation to the deposition of the egg of the next generation.

The terms used in this bulletin may be defined as follows:

The *wintering larvæ* (*spring-brood larvæ*) include all of the nontransforming larvæ of the first, second, and third broods of the preceding season.

The *spring brood of pupæ* are the pupæ from the wintering larvæ.

The *spring brood of moths* are the moths emerging from the spring brood of pupæ.

The *first generation* includes:

The first brood of eggs (deposited by spring-brood moths).
The first brood of larvæ, both transforming and wintering.
The first brood of pupæ.
The first brood of moths.

The *second generation* includes:

The second brood of eggs (deposited by first-brood moths).
The second brood of larvæ, both transforming and wintering.
The second brood of pupæ.
The second brood of moths.

The *third generation* (not complete in Washington) includes:

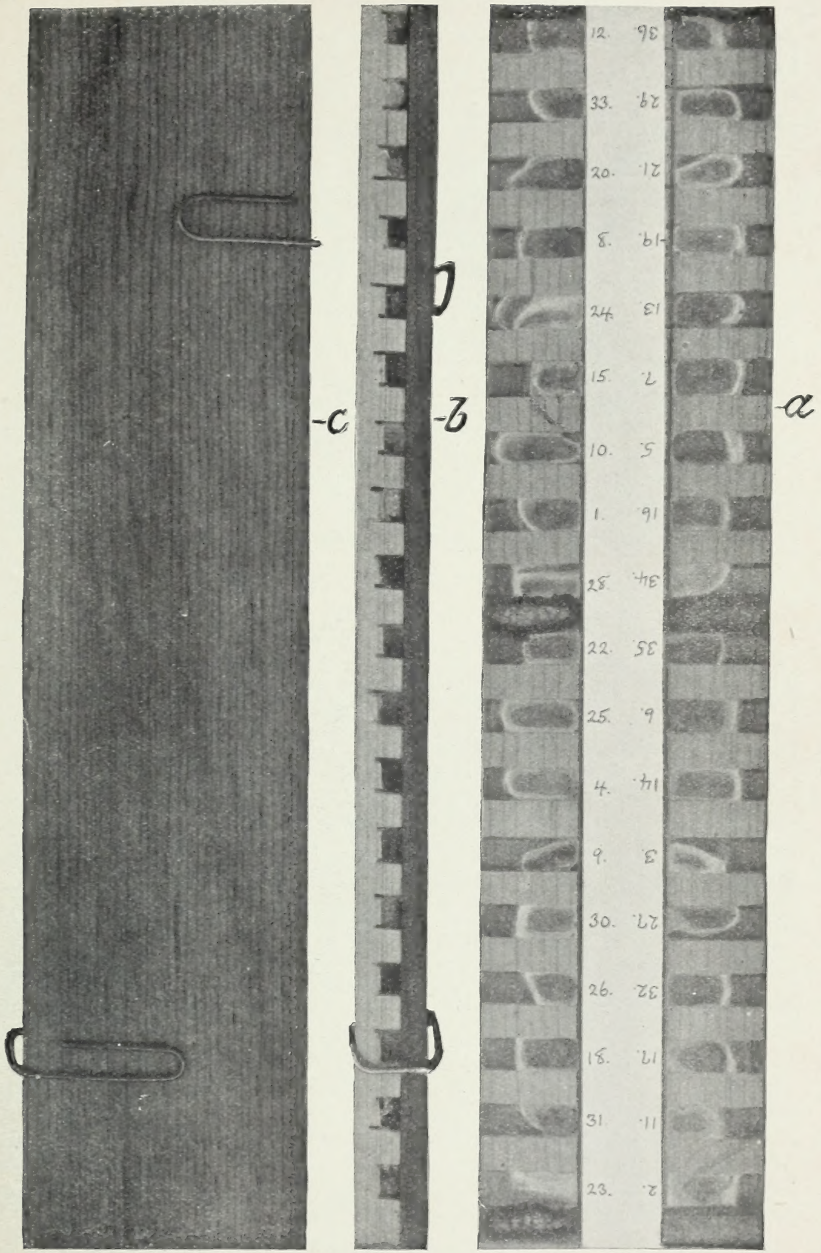
The third brood of eggs (deposited by second-brood moths).
The third brood of larvæ, all of which are wintering larvæ.

METHODS AND REARING APPARATUS EMPLOYED IN THE LIFE-HISTORY STUDIES.

The method of procedure followed in the life-history work in Yakima was similar to that followed in other investigations of the codling moth by the bureau, the object being to obtain data easily comparable to those from other sections of the country.

All of the rearing cages were glass battery jars, 6 by 8 inches, covered with coarsely woven cloth tops held in place by rubber bands and containing a layer of slightly moist sand in the bottom.

Pupation studies.—Wintering larvæ in the cells of cocooning racks were confined in the battery-jar cages and observed daily for the



THREE VIEWS OF COCOONING RACK: *a*, WITH COVER REMOVED TO SHOW THE COCOONING CELLS; *b*, SIDE VIEW; *c*, TOP VIEW

THE CODLING MOTH IN THE YAKIMA VALLEY OF WASHINGTON

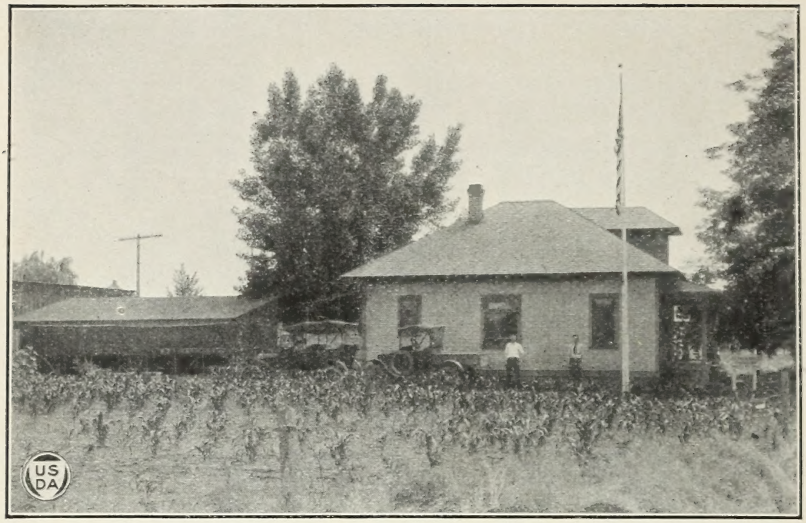


FIG. 1.—VIEW OF LABORATORY AND INSECTARY

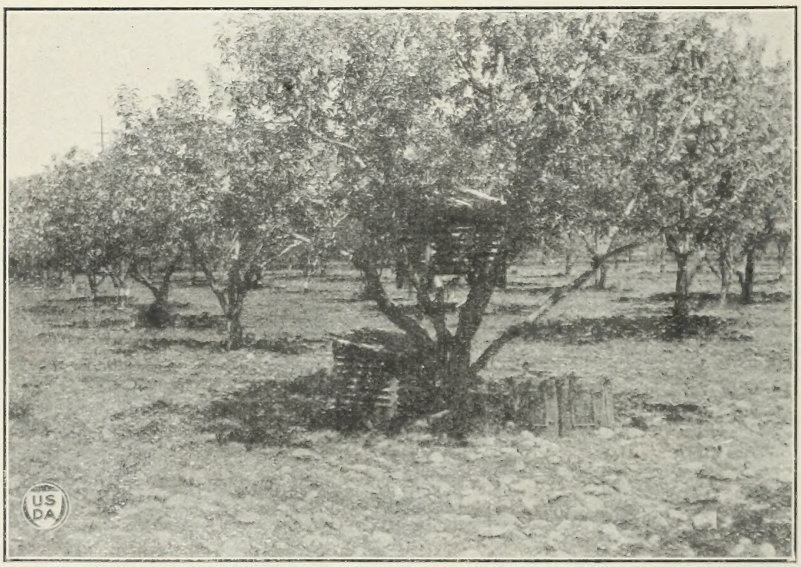


FIG. 2.—VIEW IN EXPERIMENTAL ORCHARD SHOWING SOIL CAGES, ONE BAND CAGE, AND SHELTERS FOR AIR AND SOIL THERMOGRAPHS

time of pupation. The cocooning rack (Pl. I) consists of a strip of soft wood 7¾ inches long, 1¾ inches wide, and one-fourth inch thick. On one side of this a central longitudinal groove is cut one-eighth inch deep and one-half inch wide. In this is glued a strip of hard wood, and on each side of it is a row of transverse cells extending to the edge of the rack, each cell being one-eighth inch wide and one-eighth inch deep. The hardwood strip prevents the larvæ from boring through to the cell on the opposite side. Each row of cells is covered with a strip of transparent celluloid, and a strip of paper is pasted to the hardwood, on which to record the number of each cell. The whole rack is covered with a thin strip of wood, held in place by wire paper clips.

Studies of the pupal period were made from the same cages as the pupation studies, the date of emergence of the moth being recorded daily.

Studies of moth emergence.—Each morning, before the heat of the day, moths emerging on the preceding day were counted and placed in oviposition jars.

Studies of oviposition.—Moths were confined in the regular battery-jar cages, in which were fresh pear leaves and a small sponge moistened in a solution of brown sugar. The number of moths in each cage was limited to about 25, those issuing each day being confined together, but separated from those issuing on other days. The leaves were removed daily, the eggs counted, the sponge remoistened, and fresh leaves put in the cage. No effort was made to control the number of male or female moths in each cage.

Studies of the length of life of the moths.—At the daily examination of the oviposition cages all dead moths were removed and their sex and length of life recorded.

Studies of the incubation period.—Leaves on which eggs had been deposited were placed between sheets of wire cloth in battery-jar cages to prevent them from curling. Daily observations to determine the appearance of the "red ring," which is probably the germ band, the "black spot," which is the black head and cervical shield of the young larva, and the time of hatching were made. These observations were made in the evening after the heat of the day. The number of eggs hatching was determined from the empty eggshells rather than from the number of young larvæ observed. Worm-free apples were placed in the incubation cages, in order that the worms might begin feeding immediately after hatching. These apples were removed daily and fresh apples substituted.

Studies of the larval feeding period.—Apples containing newly hatched larvæ from the incubation cages were placed in wire baskets in regular cages each day. At the end of 10 days, cocooning racks were placed in the cages and these examined daily, the number and date of larvæ leaving the fruit being recorded. This is called the "stock-jar feeding method." In the "bagged-fruit feeding method," newly hatched larvæ were placed on worm-free apples in the orchard and confined by well-ventilated paper sacks for 10 days, after which they were brought to the insectary and handled as in the stock-jar method.

THE INSECTARY.

Practically all of the life-history studies of the codling moth were made in the insectary, which was located in the rear of the laboratory (Pl. II, fig. 1). This was a frame structure 30 feet long by 12 feet wide, with a slanting roof dropping 40 inches to a minimum height of 8 feet. The sides were covered with wire screen, permitting a good circulation of air and preventing the escape of moths and the entrance of intruders. It was shaded and protected from the wind by several buildings, a large tree, and canvas awnings.

A thermograph and maximum and minimum thermometers in the insectary were used to compute the temperature records referred to in this bulletin in connection with the charts and diagrams. A thermograph operated in the orchard where the spraying experiments were conducted showed the temperatures there to have a lower maximum and a higher minimum, but showed that the monthly mean temperatures for the growing season were only 0.79° F. higher than those at the insectary. The climatological data given in Table 1 are taken from the records of the United States Weather Bureau station, which is about 3 miles from the insectary, and show the monthly mean temperatures of the same period to be higher by 4.1° F. The daily mean temperatures reported by the Weather Bureau are determined by averaging the maximum and minimum temperatures for the day. Those obtained in the insectary and orchard were computed by weighting the hourly readings recorded by the thermographs for the seasons of 1919 and 1920, while for 1921 the daily average temperatures were computed from the thermograph records for each two hours.

SEASONAL-HISTORY STUDIES OF 1919.

The seasonal-history studies of the codling moth were commenced in the spring of 1919 with observations on the pupation period of wintering larvæ. The season of 1919 began with approximately normal temperatures, but an abnormal drop occurred on May 29 and 30, the minimum temperature on the latter date being 32° F. The mean temperature for June was below normal, after which the weather was about normal for the rest of the fruit season. The rainfall was deficient, the year's total being 5.5 inches, or 1.79 inches below normal. Apple trees bloomed at Yakima April 25 to 30, and the calyx spray was applied about May 10.

The tables showing the seasonal history of the various stages should be considered separately, as, owing to accidents, natural mortality, or the removal of individuals for other reasons, it is not possible to carry all the individuals through all stages. The life-cycle tables, however, summarize the life history of those individuals which were reared from the egg to the adult stage

WINTERING LARVÆ.

Wintering larvæ construct heavy, closely woven cocoons, usually well hidden under pieces of loosened bark on the tree trunk, in the crotches of the tree, and in the soil at its base. When the weather begins to warm up in the spring the larva opens one end of the cocoon and forms a silken exit tube to the nearest place free from obstruction, through which the pupa wriggles when ready to disclose the moth.

Material for the seasonal-history studies of 1919 was obtained from banded apple trees in the vicinity of Yakima. The larvæ were collected early in March, before the exit tubes had been constructed, and were allowed to spin new cocoons in the cocooning racks.

PUPÆ OF THE SPRING BROOD.

Time of pupation.—Daily examinations of the cocooning racks were made and the first pupa was found on March 30. No more pupated until April 8, and the last wintering larva pupated on May 30. The

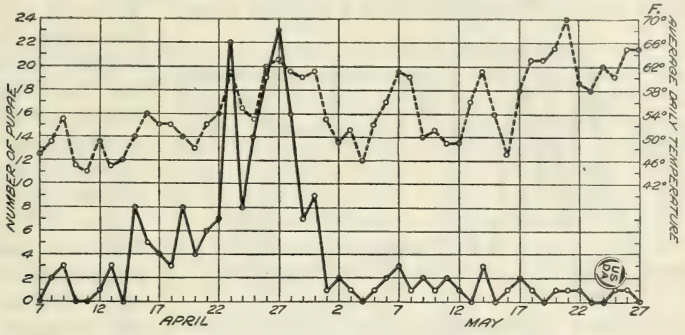


FIG. 1.—Pupation of the spring brood of the codling moth at Yakima, Wash., 1919.

period of greatest pupation extended from April 15 to April 30, with a maximum April 27. The time of pupation of 201 individuals is illustrated in Figure 1.

Length of the pupal stage.—Table 2 gives the length of the pupal stage of 180 pupæ of the spring brood.

TABLE 2.—*Length of the pupal stage of pupæ of the spring brood of the codling moth, Yakima, Wash., 1919.*

Date of pupation.	Number of pupæ.	Pupal period in days.			Date of pupation.	Number of pupæ.	Pupal period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
Mar. 30	1	44.00	44	44	Apr. 29	6	31.67	34	29
Apr. 8	2	39.50	40	39	30	5	32.60	34	31
9	3	40.00	41	39	May 1	1	32.00	32	32
12	1	38.00	38	38	2	1	32.00	32	32
13	3	37.00	37	37	3	1	32.00	32	32
15	8	35.25	36	34	5	1	29.00	29	29
16	4	35.25	36	35	6	2	29.00	30	28
17	4	34.00	34	34	7	3	29.33	30	29
18	3	33.00	33	33	9	2	27.00	27	27
19	7	32.57	33	32	10	1	28.00	28	28
20	4	31.25	32	31	11	2	26.50	28	25
21	4	32.25	34	31	12	1	30.00	30	30
22	6	31.00	32	30	14	3	29.33	30	29
23	20	31.05	33	29	17	2	29.50	33	26
24	8	31.13	32	29	18	1	31.00	31	31
25	13	29.92	31	26	20	1	27.00	27	27
26	18	30.28	31	29	21	1	28.00	28	28
27	22	31.23	35	29	30	1	27.00	27	27
28	14	31.14	34	29					

Total number of pupæ	180
Average length of pupal period in days	31.63
Maximum length of pupal period in days	44
Minimum length of pupal period in days	25

MOTHS OF THE SPRING BROOD.

Time of emergence.—The first moth emerged May 13, about two weeks after the apple trees were in full bloom. Moths continued to emerge until June 19, as shown in Figure 2, with a final straggler on June 26. The maximum period of emergence occurred from May 18 to June 5, with a maximum of 85 moths on May 21. On May 29 and 30 there was a decided drop in the temperature, resulting in a temporary falling off of the number of moths emerging. Otherwise the emergence curve is fairly regular.

Oviposition by moths of the spring brood.—Oviposition records were obtained from 579 moths of the spring brood. One lot of moths, emerging May 27, began ovipositing the next day, but the interval before oviposition averaged 5.53 days, with a maximum of 18 days. The interval before maximum oviposition averaged 9.93 days, with an average oviposition period of 14.67 days and an average time from emergence to last oviposition of 19.2 days. All these data are given in Table 3. It must be borne in mind that these averages are for cages and not for individuals. Some individual averages will be found on page 67.

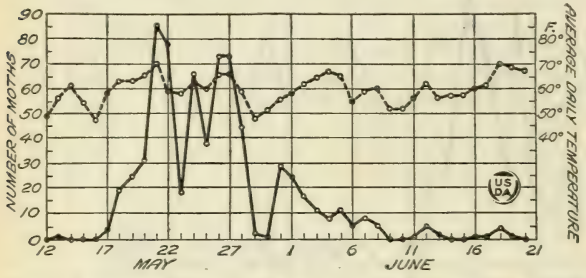


FIG. 2.—Emergence of the spring brood of moths of the codling moth at Yakima, Wash., 1919.

TABLE 3.—*Oviposition by codling moths of the spring brood in rearing cages, Yakima, Wash., 1919.*

Observation.	Number of moths.	Sex.		Date of—				Number of days—				Total number of eggs deposited.
		Male.	Female.	Emergence.	First oviposition.	Maximum oviposition.	Last oviposition.	Before oviposition.	From emergence to maximum oviposition.	Of oviposition.	From emergence to last oviposition.	
1	19	14	5	May 18	May 21	May 28	June 5	3	10	16	18	13
2	24	14	10	May 19	June 6	June 6	June 16	18	18	11	28	10
3	26	18	8	May 20	May 22	May 26	June 5	2	6	15	16	43
4	75	34	41	May 21	May 23	June 1	June 15	2	11	24	25	212
5	74	42	32	May 22	May 26	June 8	...do.....	4	12	21	24	202
6	18	9	9	May 23	May 31	June 6	June 16	8	14	17	24	40
7	50	18	32	May 24	May 26	June 4	...do.....	2	11	22	23	450
8	25	14	11	May 25	June 1	June 1	...do.....	7	7	16	22	157
9	74	35	39	May 26	...do.....	June 4	June 17	6	9	17	22	112
10	72	32	40	May 27	May 28	June 3	June 14	1	7	18	18	493
11	43	16	27	May 28	June 1	June 4	June 15	4	7	15	18	130
12	26	12	14	May 31	June 7	June 7	June 8	7	7	2	8	4
13	26	10	16	June 1	...do.....	June 16	June 16	6	15	10	15	21
14	17	8	9	June 2	June 12	June 14	...do.....	10	12	5	14	15
15	10	3	7	June 3	June 6	June 6	...do.....	3	3	11	13	5
Average								5.53	9.93	14.67	19.20	.....
Maximum								18	18	24	28	.....
Minimum								1	3	2	8	.....

Number of male moths	279
Number of female moths	300
Total number of moths	579
Total number of eggs	1,907
Average number of eggs per female moth	6.36

Number of eggs per female.—The average number of eggs per female in the cages from which the data given in Table 3 were secured was 6.36, 300 females depositing a total of 1,907 eggs.

Length of life of moths.—Records of the length of life of 285 male moths and 300 females were obtained from the oviposition cages, and these are given in Table 4.

TABLE 4.—*Length of life of male and female codling moths of the spring brood, Yakima, Wash., 1919.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life	Number of moths.	Length of life.	Number of moths.
Days		*Days*		*Days.*		*Days.*		*Days.*		*Days.*	
1	1	1	0	12	10	12	7	23	12	23	13
2	2	2	4	13	16	13	18	24	4	24	6
3	5	3	1	14	13	14	8	25	9	25	8
4	12	4	3	15	16	15	19	26	15	26	8
5	9	5	3	16	18	16	16	27	8	27	9
6	7	6	7	17	14	17	27	28	5	28	2
7	12	7	5	18	12	18	18	29	0	29	1
8	11	8	9	19	5	19	19				
9	8	9	6	20	14	20	28	Total..	285	Total..	300
10	13	10	11	21	7	21	13				
11	10	11	8	22	17	22	23				

Average length of life of male moths, 15.33 days; female moths, 16.91 days.
Maximum length of life, male moths, 28 days; female moths, 29 days.
Minimum length of life, male moths, 1 day; female moths, 2 days.

THE FIRST GENERATION.

EGGS OF THE FIRST BROOD.

Time of egg deposition.—Spring-brood moths in the insectary began ovipositing May 21, and with the exception of two days eggs were deposited every day until June 24. These two days were May 29 and 30, which were abnormally cold. The oviposition record is delineated in Figure 3. As shown on page 64, the majority of the eggs are deposited between 3 and 9 p. m. The average temperature for this 6-hour period is therefore given on the diagram, instead of the usual average daily temperature. A reference to Tables 52 and 53 will show also that as the temperature decreases the number of eggs deposited diminishes, until at 60° F. and lower it is rare for any eggs at all to be deposited. Figure 3 shows graphically how closely the number of eggs deposited follows the fluctuations in the temperature curve. The majority of the eggs of the first brood were deposited

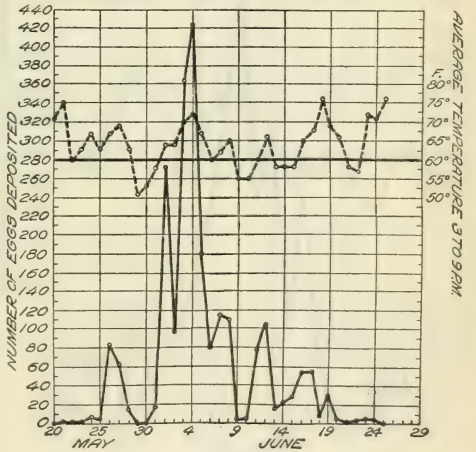


FIG. 3.—Time of deposition of eggs of the first brood of the codling moth at Yakima, Wash., 1919.

from June 1 to June 8, inclusive, with a maximum deposition of 422 eggs on June 4.

Length of incubation.—Incubation records of 837 eggs are given in Table 5. The earlier eggs required rather more than the average period for incubation, while later, when the temperature was higher, the average period was much reduced.

TABLE 5.—*Time of deposition and length of incubation of eggs of the first brood of the codling moth, Yakima, Wash., 1919.*

Date of deposition.	Number of eggs.	Number of days from deposition to appearance of—						Incubation period in days.		
		Red ring.			Black spot.			Average.	Maximum.	Minimum.
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.			
May 26	35	5.00	5	5	11.00	11	11	12.91	14	12
27	10	3.00	3	3	9.00	9	9	11.30	12	11
June 1	61	3.00	3	3	10.61	11	9	12.65	14	12
2	38	3.00	3	3	10.00	10	10	12.00	12	12
3	161	3.00	3	3	10.21	11	10	13.02	14	12
4	218	5.00	5	5	10.14	11	10	13.96	15	13
5	76	5.00	5	5	12.67	13	12	14.47	16	14
6	34	6.00	6	6	12.00	12	12	13.29	14	13
7	33	7.00	7	7	10.00	10	10	13.18	14	13
8	45	8.00	8	8	10.00	10	10	12.51	13	12
9	2	8.00	8	8	10.00	10	10	11.50	12	11
11	14	7.00	7	7	9.00	9	9	10.43	11	10
12	36	7.00	7	7	9.00	9	9	10.28	11	10
13	10	7.00	7	7	8.00	8	8	9.90	11	9
14	10	6.00	6	6	8.00	8	8	9.30	10	9
15	6	6.00	6	6	7.00	7	7	9.00	9	9
16	3	6.00	6	6	8.00	8	8	9.00	9	9
17	39	6.00	6	6	7.00	7	7	8.05	9	8
18	1	5.00	5	5	7.00	7	7	8.00	8	8
20	2	4.00	4	4	7.00	7	7	9.00	9	9
23	3	3.00	3	3	5.00	5	5	6.00	6	6
	837	4.85	8	3	10.17	13	5	12.73	16	6

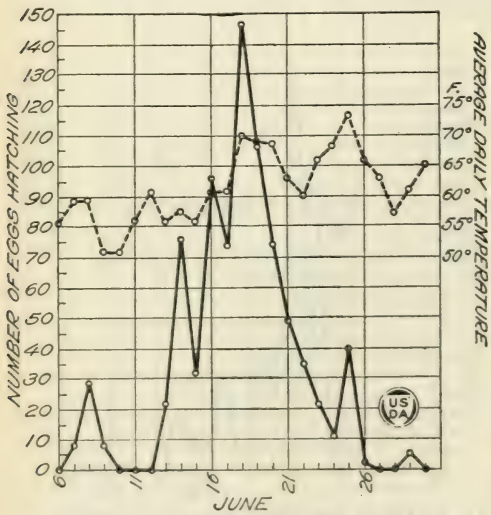


FIG. 4.—Hatching of larvæ of the first brood of the codling moth at Yakima, Wash., 1919.

LARVÆ OF THE FIRST BROOD.

Time of hatching.—First-brood larvæ began hatching in the insectary on June 7 (fig. 4), and continued until June 29, a total period of 23 days. On June 10, 11, and 12, no larvæ hatched, owing not so much to low temperatures at this time as to the fact that no eggs were deposited on May 29 and 30. The majority of larvæ hatched from June 16 to 20, inclusive, the maximum of 147 occurring on June 18, 11 days after the first larva hatched.

Length of the feeding period, stock-jar method.—Table 6 gives the length of the feeding period of 135 first-brood larvæ (both transforming and nontransforming) in stock jars (see p. 5).

TABLE 6.—*Length of feeding period of larvæ of the first brood of the codling moth, stock-jar method, Yakima, Wash., 1919.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
June 14	6	25.67	28	24	June 22	5	25.60	29	23
16	12	25.34	28	21	23	6	22.50	24	21
18	26	24.15	33	20	24	2	22.50	23	22
19	23	24.17	32	19	25	16	21.63	25	18
20	18	23.78	30	20	26	1	30.00	30	30
21	18	23.50	33	20	28	2	19.50	21	18

Total number of larvæ 135
Average length of feeding period in days 23.82
Maximum length of feeding period in days 33
Minimum length of feeding period in days 18

Length of the feeding period, bagged-fruit method.—The length of the feeding period of 70 larvæ (both transforming and nontransforming) reared by the bagged-fruit method (see p. 5) is given in Table 7. Larvæ reared by this method occupied a slightly longer time in feeding than where reared by the stock-jar method.

TABLE 7.—*Length of feeding period of larvæ of the first brood of the codling moth, bagged-fruit method, Yakima, Wash., 1919.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
June 7	3	25.00	26	24	June 18	3	25.00	27	24
9	2	33.50	39	28	19	6	21.17	24	18
12	3	24.33	26	22	20	15	25.33	33	22
13	6	27.50	29	25	21	5	23.40	26	21
16	10	24.20	27	22	23	6	24.00	27	21
17	6	24.50	28	22	24	5	25.00	29	22

Total number of larvæ 70
Average length of feeding period in days 24.81
Maximum length of feeding period in days 39
Minimum length of feeding period in days 18

Length of the cocooning period.—The cocooning period represents the total time elapsing from the date the larva leaves the fruit until it pupates, although the actual period of constructing the cocoon is necessarily somewhat shorter. In Table 8 will be found data showing the cocooning period of 146 transforming individuals of the first brood.

TABLE 8.—*Length of cocooning period of transforming codling moth larvæ of the first brood, Yakima, Wash., 1919.*

Larvæ left fruit.	Number of larvæ.	Cocooning period in days.			Larvæ left fruit.	Number of larvæ.	Cocooning period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 1	1	6.00	6	6	July 14	17	9.59	28	4
2	1	6.00	6	6	15	22	8.36	26	3
3	1	5.00	5	5	16	12	7.25	26	5
4	1	4.00	4	4	17	3	10.33	21	4
7	1	5.00	5	5	18	3	4.67	6	4
8	9	4.56	5	4	19	6	6.67	15	4
9	8	5.25	9	4	20	2	11.00	16	6
10	10	4.80	5	4	21	1	15.00	15	15
11	11	4.91	8	4	23	1	6.00	6	6
12	21	6.81	25	4	24	1	6.00	6	6
13	14	7.07	21	4					
						146	6.99	28	3

PUPÆ OF THE FIRST BROOD.

Time of pupation.—Transforming larvæ of the first brood began pupating July 7, and continued until August 12, the largest number pupating from July 13 to 23, with the maximum July 19. (See Fig. 5.)

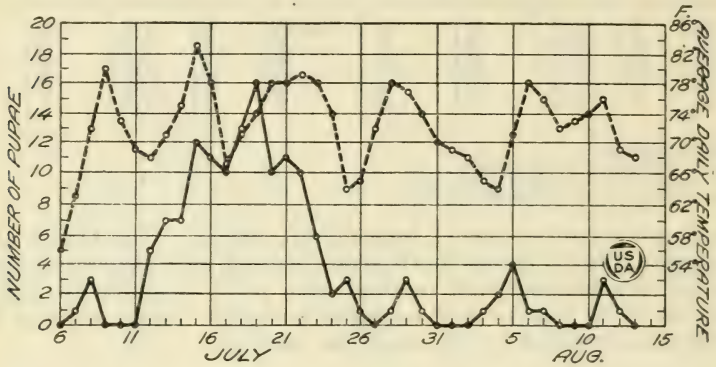


FIG. 5.—Pupation of the first brood of the codling moth at Yakima, Wash., 1919.

Length of pupal stage.—Data on the length of the pupal stage of the first brood of pupæ were secured from 128 individuals, as indicated in Table 9.

TABLE 9.—*Length of the pupal stage of pupæ of the first brood of the codling moth, Yakima, Wash., 1919.*

Date of pupation.	Number of pupæ.	Pupal period in days.			Date of pupation.	Number of pupæ.	Pupal period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 7	1	12.00	12	12	July 23	6	14.00	17	9
8	2	11.50	12	11	24	1	13.00	13	13
12	4	11.00	12	10	25	3	13.33	14	12
13	7	12.43	14	10	26	1	15.00	15	15
14	5	12.60	13	11	28	1	14.00	14	14
15	11	12.55	15	11	29	3	15.33	16	15
16	9	12.22	13	11	30	1	13.00	13	13
17	9	12.11	13	11	Aug. 3	1	14.00	14	14
18	12	13.42	21	12	4	2	13.50	14	13
19	13	17.31	44	11	5	4	13.25	14	13
20	9	12.89	15	10	6	1	15.00	15	15
21	11	16.27	44	10	7	1	12.00	12	12
22	8	17.75	37	13	11	2	13.00	14	12

Total number of pupæ	128
Average length of the pupal stage in days	13.91
Maximum length of the pupal stage in days	44
Minimum length of the pupal stage in days	9

MOTHS OF THE FIRST BROOD.

Time of emergence.—Figure 6 combines the records of emergence of the first brood of moths from insectary-bred material and from band-record material. The first moth emerged July 8, the last, September 24, and the maximum number, July 19. From the insectary-bred material, the first moth was secured July 19, the last September 3, and the maximum July 30. Some, if not most, of the moths emerging in September from the band-record material were probably second-brood moths, as several second-brood moths emerged from the insectary-bred material at this time. There is some overlapping, as evidenced by the fact that the first moth of the second

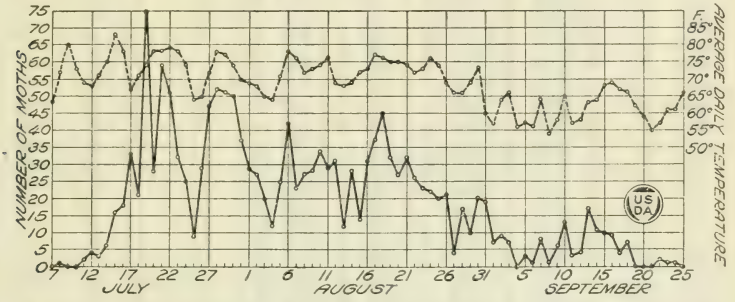


FIG. 6.—Emergence of the first and second broods of moths of the codling moth at Yakima, Wash., 1919.

brood emerged August 29, while the last of the first brood emerged September 3. For this reason, and because the second brood is quite small, the records of the two have been combined.

Oviposition by moths of the first brood.—As the spraying schedule in the Yakima Valley requires an application of spray for the earliest worms of the second brood, it is important to obtain the earliest date of oviposition. On account of this, moths emerging from the band-record material collected in the field were used for obtaining oviposition records, as the larvæ from which they were reared had been under natural conditions. A total of 1,251 moths were used. In most cases these moths began ovipositing the day following their emergence. (See Table 10.) The averages are for cages and not individuals. For some individual averages see page 69.

TABLE 10.—*Oviposition by codling moths of the first brood in rearing cages, Yakima, Wash., 1919.*

Observation.	Number of moths.	Sex.		Date of—				Number of days—				Total number of eggs deposited.
		Male.	Female.	Emergence.	First oviposition.	Maximum oviposition.	Last oviposition.	Before oviposition.	From emergence to maximum oviposition.	Of oviposition.	From emergence to last oviposition.	
1	18	7	11	July 16	July 18	July 21	Aug. 4	2	5	18	19	167
2	32	17	15	July 17	...do.....	July 20	July 26	1	3	9	9	196
3	21	10	11	July 18	July 20	...do.....	Aug. 3	2	2	15	16	144
4	74	40	34	July 19	...do.....	...do.....	Aug. 7	1	1	19	19	923
5	25	10	15	July 20	July 21	July 21	Aug. 3	1	1	14	14	406
6	58	25	33	July 21	July 22	July 23	Aug. 9	1	2	19	19	481
7	46	23	23	July 22	July 23	July 29	Aug. 5	1	7	14	14	237
8	20	11	9	July 23	July 26	July 30	Aug. 3	3	7	9	11	108
9	23	14	9	July 24	...do.....	July 29	Aug. 9	2	5	15	16	209
10	29	14	15	July 26	July 29	Aug. 1	Aug. 6	3	6	9	11	248
11	33	10	23	July 27	July 28	July 29	Aug. 9	1	2	13	13	657
12	36	11	25	July 28	July 29	...do.....	...do.....	1	1	12	12	720
13	36	11	25	July 29	July 30	July 31	Aug. 11	1	2	13	13	930
14	50	27	23	July 30	July 31	Aug. 7	Aug. 19	1	8	20	20	667
15	30	15	15	July 31	Aug. 2	Aug. 5	Aug. 18	2	5	17	18	291
16	19	10	9	Aug. 1	...do.....	...do.....	Aug. 10	1	4	9	9	376
17	27	16	11	Aug. 2	Aug. 5	...do.....	Aug. 14	3	3	10	12	129
18	21	7	14	Aug. 3	Aug. 6	Aug. 6	Aug. 21	3	3	16	18	356
19	25	11	14	Aug. 5	...do.....	Aug. 9	Aug. 15	1	4	10	10	750
20	40	17	23	Aug. 6	Aug. 7	Aug. 7	Aug. 24	1	1	18	18	249
21	22	10	12	Aug. 7	Aug. 8	Aug. 10	Aug. 11	1	3	4	4	66
22	27	13	14	Aug. 8	Aug. 9	Aug. 9	Aug. 18	1	1	10	10	465
23	28	9	19	Aug. 9	Aug. 12	Aug. 12	Sept. 4	3	3	24	26	254
24	31	15	16	Aug. 10	Aug. 11	Aug. 14	Aug. 21	1	4	11	11	508
25	27	6	21	Aug. 11	Aug. 14	Aug. 18	Aug. 29	3	7	16	18	229
26	33	13	20	Aug. 12	...do.....	...do.....	Aug. 25	2	6	12	13	543
27	27	11	16	Aug. 14	Aug. 15	Aug. 15	Aug. 27	1	1	13	13	179
28	14	6	8	Aug. 15	Aug. 17	Aug. 18	Aug. 25	2	3	9	10	211
29	30	9	21	Aug. 16	Aug. 18	Aug. 20	Sept. 3	2	4	17	18	610
30	37	18	19	Aug. 17	...do.....	...do.....	Sept. 2	1	3	16	16	207
31	45	19	26	Aug. 18	Aug. 19	Aug. 21	Aug. 31	1	3	13	13	585
32	32	16	16	Aug. 19	Aug. 20	Aug. 20	Sept. 10	1	1	22	22	448
33	27	12	15	Aug. 20	Aug. 21	Aug. 23	Sept. 4	1	3	15	15	396
34	32	12	20	Aug. 21	Aug. 22	Aug. 25	Sept. 10	1	4	20	20	480
35	26	11	15	Aug. 22	Aug. 23	Sept. 2	Sept. 13	1	11	22	22	338
36	22	10	12	Aug. 23	Aug. 24	Aug. 25	...do.....	1	2	21	21	315
37	21	8	13	Aug. 24	Aug. 25	Aug. 28	Sept. 10	1	4	17	17	190
38	21	12	9	Aug. 25	Aug. 26	Aug. 30	Sept. 13	1	5	19	19	286
39	21	9	12	Aug. 26	Aug. 28	...do.....	...do.....	2	4	17	18	320
40	16	5	11	Aug. 28	Sept. 1	Sept. 2	Sept. 16	4	5	16	19	685
41	10	4	6	Aug. 29	...do.....	Sept. 7	Sept. 13	3	9	13	15	228
42	20	10	10	Aug. 30	Sept. 2	Sept. 13	Sept. 18	3	14	17	19	216
43	19	11	8	Aug. 31	Sept. 1	Sept. 9	Sept. 20	1	9	20	20	276
Average								1.63	4.21	14.95	15.58	.....
Maximum								4	14	24	26	.....
Minimum								1	1	4	4	.....

Number of male moths	555
Number of female moths	696
Total number of moths	1,251
Total number of eggs	16,279
Average number of eggs per female moths	23.39

Number of eggs per female moth.—Table 10 shows that 696 female moths deposited 16,279 eggs, or an average of 23.39 eggs per female.

Length of life of moths.—Table 11 shows that of 555 male moths and 694 female moths, the males lived slightly longer.

TABLE 11.—*Length of life of male and female codling moths of the first brood, Yakima, Wash., 1919.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
1	0	1	2	15	21	15	40	29	8	29	1
2	2	2	3	16	21	16	33	30	1	30	1
3	5	3	4	17	23	17	24	31	3	31	2
4	10	4	4	18	24	18	27	32	1	32	0
5	6	5	9	19	20	19	15	33	1	33	1
6	26	6	17	20	19	20	15	34	3	34	0
7	42	7	39	21	15	21	19	36	0	36	1
8	41	8	56	22	13	22	15	37	0	37	1
9	45	9	66	23	8	23	7	38	1	38	0
10	40	10	73	24	8	24	11	39	2	39	0
11	26	11	62	25	9	25	9	44	1	44	0
12	32	12	55	26	6	26	6	45	1	45	0
13	35	13	40	27	7	27	4				
14	26	14	27	28	3	28	5	Total.	555	Total.	694

Average length of life of male moths, 13.97 days; female moths, 13.09 days.
Maximum length of life of male moths, 45 days; female moths, 37 days.
Minimum length of life of male moths, 2 days; female moths, 1 day.

LIFE CYCLE OF THE FIRST GENERATION.

Life cycle, stock-jar feeding method.—Table 12 gives the life cycle of 78 individuals of the first generation, all of which were reared from egg to moth, the larvæ being fed by the stock-jar method. The incubation period averaged 12.18 days, larval feeding period 23.59 days, cocooning period 7.69 days, pupal period 13.33 days; a total of 56.79 days for the life cycle. In order to arrive at the complete life cycle from deposition of first-brood egg to deposition of second-brood egg 1.63 days should be added, which is the average interval between emergence of the first-brood moth and egg deposition. This gives a complete cycle of 58.42 days.

TABLE 12.—*Life cycle of the first generation of the codling moth as observed by rearing, stock-jar feeding method, Yakima, Wash., 1919.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.[1]		
			Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
		Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
June 2	5	12	25.40	28	24	8.60	25	4	13.00	15	11	59.00	80	51
3	6	13	25.83	28	22	6.50	11	4	12.83	16	10	58.16	64	53
4	12	14	24.08	31	21	6.83	15	5	13.50	15	12	58.41	74	53
5	7	14	23.86	32	19	13.00	21	4	12.14	14	10	63.00	74	48
7	14	13	24.07	30	20	7.28	19	4	14.42	37	11	58.77	82	49
8	15	13	23.07	33	20	6.67	28	4	13.27	15	10	56.01	78	49
12	2	10	23.50	24	23	5.50	6	5	13.00	13	13	52.00	52	52
12	4	11	22.50	24	21	14.25	26	5	12.00	12	12	59.75	72	49
15	1	9	23.00	23	23	6.00	6	6	14.00	14	14	52.00	52	52
17	11	8	21.91	24	18	5.82	10	4	13.64	15	9	49.37	53	45
20	1	8	18.00	18	18	5.00	5	5	12.00	12	12	43.00	43	43
	78	12.18	23.59	33	18	7.69	28	4	13.33	37	9	56.79	82	43

[1] Add 1.63 days for complete life cycle.

Life cycle, bagged-fruit feeding method.—In Table 13 are shown the life-cycle figures for 48 individuals of the first generation, the larvæ of which were fed by the bagged-fruit method.

TABLE 13.—*Life cycle of the first generation of the codling moth as observed by rearing, bagged-fruit feeding method, Yakima, Wash., 1919.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.[1]		
			Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
		Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
May 26	2	12	25.00	26	24	5.50	6	5	12.00	12	12	54.50	55	54
June 1	3	11	24.33	25	22	4.67	5	4	11.67	13	11	51.67	55	48
1	3	12	26.67	28	25	4.67	5	4	12.33	13	12	55.67	58	53
3	5	13	24.00	26	22	4.60	6	4	12.60	14	10	54.20	59	49
3	4	14	23.50	25	22	5.00	6	4	13.00	14	12	55.50	57	54
4	2	14	25.50	27	24	5.00	6	4	13.00	13	13	57.50	60	55
5	6	14	23.17	26	20	5.33	6	4	17.83	44	11	60.33	88	50
8	11	12	24.55	30	22	5.36	7	5	13.73	19	11	55.64	63	50
8	3	13	22.67	24	21	4.00	5	3	11.67	12	11	51.34	52	50
12	5	11	23.40	27	21	5.20	6	5	12.40	14	11	52.00	57	48
15	4	9	25.25	29	22	4.75	6	4	22.25	44	13	61.25	80	51
	48	12.25	24.23	30	20	5.00	7	3	14.19	44	10	55.67	88	48

[1] Add 1.63 days for complete life cycle.

THE SECOND GENERATION.

EGGS OF THE SECOND BROOD.

Time of deposition.—The first eggs of the second brood were deposited by first-brood moths on July 15, and eggs were deposited

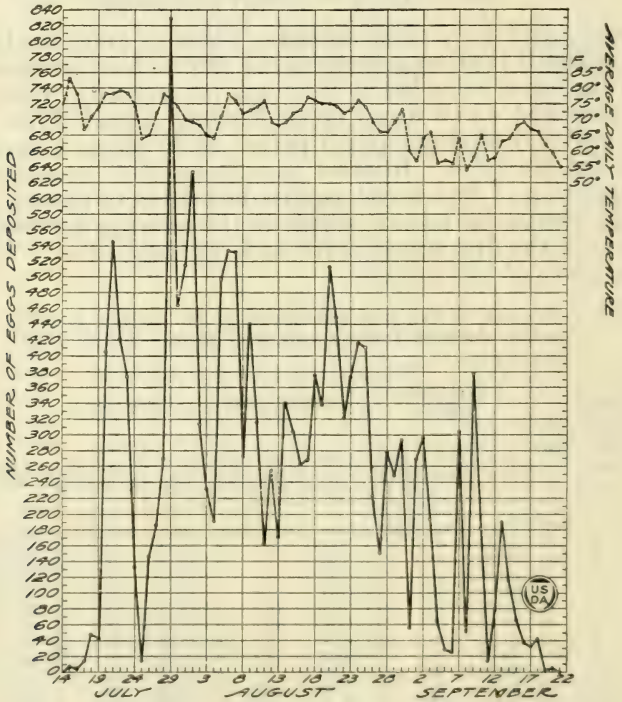


FIG. 7.—Time of deposition of eggs of the second brood of the codling moth at Yakima, Wash., 1919.

daily until September 20, as shown in Figure 7. The maximum period of oviposition is less decided and much longer than that of the spring brood of moths (see p. 9). It extended from the latter part of July until nearly the last of August, with an actual maximum of 829 eggs on July 29.

Length of incubation.—Data on this phase of the life history are set forth in Table 14. The average incubation period of 8.72 days is not much more than half that of the first brood of eggs.

TABLE 14.—*Time of deposition and length of incubation of eggs of the second brood of the codling moth, Yakima, Wash., 1919.*

Date of deposition.	Number of eggs.	Number of days from deposition to appearance of—						Incubation period in days.		
		Red ring.			Black spot.					
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
July 15	3	3.00	3	3	6.00	6	6	7.00	7	7
17	4	2.00	2	2	5.00	5	5	7.00	7	7
18	27	2.00	2	2	6.00	6	6	7.22	8	7
19	8	3.00	3	3	5.00	5	5	6.63	7	6
20	52	2.00	2	2	5.48	6	5	7.48	8	7
21	118	2.00	2	2	6.00	6	6	7.25	8	7
22	162	2.00	2	2	6.00	6	6	7.10	8	7
23	99	2.00	2	2	6.00	6	6	7.04	8	7
24	44	2.00	2	2	6.00	6	6	7.55	9	7
26	90	2.00	2	2	6.00	6	6	7.62	8	7
27	106	2.00	2	2	6.00	6	6	7.66	8	7
28	76	2.00	2	2	6.28	7	6	8.28	9	8
29	359	2.00	2	2	7.27	8	7	8.53	10	8
30	213	2.00	2	2	7.00	7	7	8.13	9	8
31	261	2.00	2	2	7.00	7	7	8.17	9	8
Aug. 1	231	3.00	3	3	7.00	7	7	8.26	9	8
2	135	2.00	2	2	7.00	7	7	8.01	9	8
3	77	2.00	2	2	7.00	7	7	8.34	9	8
4	102	2.00	2	2	6.00	6	6	7.16	8	7
5	201	2.00	2	2	6.00	6	6	7.19	8	7
6	151	2.00	2	2	6.00	6	6	7.00	7	7
7	130	2.00	2	2	6.00	6	6	7.60	9	7
8	59	2.00	2	2	6.00	6	6	7.90	8	7
9	120	2.00	2	2	6.00	6	6	7.04	8	7
10	115	2.00	2	2	6.00	6	6	7.22	8	7
12	64	2.00	2	2	6.00	6	6	7.00	7	7
13	91	2.00	2	2	6.00	6	6	7.08	8	7
14	108	2.00	2	2	6.00	6	6	7.03	8	7
15	56	2.00	2	2	6.00	6	6	7.07	8	7
16	104	2.00	2	2	6.00	6	6	7.02	8	7
17	59	2.00	2	2	6.00	6	6	7.10	8	7
18	31	2.00	2	2	6.00	6	6	7.16	8	7
19	28	2.00	2	2	6.00	6	6	7.07	8	7
20	58	2.00	2	2	6.00	6	6	7.12	8	7
21	158	2.00	2	2	6.00	6	6	7.72	8	7
22	52	2.00	2	2	6.94	7	6	8.06	9	7
23	100	2.00	2	2	7.00	7	7	8.05	9	8
24	94	2.00	2	2	7.00	7	7	9.27	10	9
25	101	2.00	2	2	8.00	8	8	10.19	12	10
26	36	2.00	2	2	9.00	9	9	12.50	14	12
27	22	2.86	3	2	10.86	11	10	12.05	13	11
29	158	2.00	2	2	10.85	13	10	12.61	15	11
30	109	2.00	2	2	13.00	13	13	15.49	17	14
31	14	1.00	1	1	14.00	14	14	15.71	17	15
Sept. 1	29	2.00	2	2	14.00	14	14	15.66	17	15
2	103	2.00	2	2	14.00	14	14	16.29	17	15
3	54	4.00	4	4	13.00	13	13	14.00	14	14
4	18	5.00	5	5	12.00	12	12	13.33	14	13
7	109	5.00	5	5	9.00	9	9	10.41	11	10
9	117	4.00	4	4	9.00	9	9	10.71	12	10
10	86	4.00	4	4	9.00	9	9	11.26	12	11
13	105	3.00	3	3	8.00	8	8	10.92	12	9
14	52	3.00	3	3	9.90	9	9	11.06	12	10
15	20	4.00	4	4	9.00	9	9	11.10	12	10
	5,079	2.26	5	1	7.29	14	5	8.72	17	6

LARVÆ OF THE SECOND BROOD.

Time of hatching.—Second-brood larvæ were hatching for more than two months, beginning July 22, reaching a maximum August 7 and continuing until September 27. A reference to Figure 8 will show that the maximum period of hatching was much more prolonged than was the case with the first brood of larvæ.

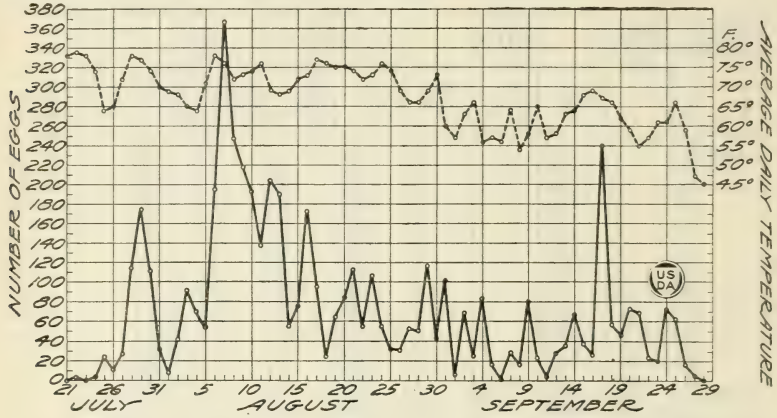


FIG. 8.—Hatching of larvæ of the second brood of the codling moth at Yakima, Wash., 1919.

Length of feeding period, stock-jar method.—Table 15 shows data of 327 larvæ of the second brood, reared by the stock-jar method.

TABLE 15.—*Length of feeding period of larvæ of the second brood of the codling moth, stock-jar method, Yakima, Wash., 1919.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 22	3	26.00	32	22	Aug. 14	7	24.71	26	22
25	4	37.25	69	26	15	16	32.81	66	20
27	2	30.00	38	22	16	10	39.90	67	31
28	7	39.29	53	23	17	12	34.50	56	27
29	13	29.08	56	21	19	3	39.00	46	35
30	13	28.85	43	22	20	6	37.00	53	15
Aug. 1	5	28.20	36	23	21	5	44.60	52	36
2	8	29.00	39	22	22	4	52.50	57	47
3	4	26.50	28	24	23	5	44.20	60	27
4	4	30.50	38	25	24	2	47.00	47	47
5	8	29.63	43	19	25	2	49.50	56	43
6	12	34.75	61	23	26	2	59.00	63	55
7	37	29.62	40	20	27	4	44.75	54	38
8	36	33.75	57	19	28	4	54.00	61	49
9	16	38.31	62	22	30	1	51.00	51	51
10	15	37.67	46	28	31	1	52.00	52	52
11	12	35.58	56	19	Sept. 4	1	22.00	22	22
12	21	34.81	51	16	7	1	39.00	39	39
13	21	33.10	50	21					

Total number of larvæ	327
Average length of feeding period in days	34.51
Maximum length of feeding period in days	69
Minimum length of feeding period in days	15

Length of feeding period, bagged-fruit method.—In Table 16 it will be found that 93 larvæ reared by the bagged-fruit method fed an average of 29.75 days. The reason this average is less than that of the stock-jar larvæ is that this method was used only for larvæ entering the fruit for a period of two weeks, and during the time they were feeding the temperature averaged warmer than it did for the whole period of feeding of the second brood, which is covered by the stock-jar larvæ.

TABLE 16.—*Length of feeding period of larvæ of the second brood of the codling moth, bagged-fruit method, Yakima, Wash., 1919.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 26	5	28.00	34	25	Aug. 3	6	29.00	44	22
27	6	28.83	43	23	4	8	27.38	39	17
28	4	31.00	42	21	5	6	30.67	42	22
29	9	24.89	33	21	6	7	29.86	49	22
30	8	27.75	37	21	7	7	35.29	45	22
31	9	24.78	29	22	9	14	34.71	40	24
Aug. 2	4	35.50	43	27					

Total number of larvæ	93
Average length of feeding period in days	29.75
Maximum length of feeding period in days	49
Minimum length of feeding period in days	17

Length of the cocooning period.—Only five larvæ of the second brood pupated, all of them being among the earliest to leave the fruit. The cocooning period of these larvæ was 5, 6, 7, 9, and 9 days, respectively, the average being 7.20 days.

PUPÆ OF THE SECOND BROOD.

Time of pupation.—One larva pupated on August 18, one on August 26, and three on August 28.

Length of the pupal stage.—The pupal stage of these five individuals was 11, 14, 16, 19, and 20 days, respectively, the average being 16 days.

MOTHS OF THE SECOND BROOD.

Time of emergence.—The five pupæ mentioned above produced moths on August 29, September 11, 13, 15, and 16.

LIFE CYCLE OF THE SECOND GENERATION.

The life cycle of five individuals of the second generation is given in Table 17 and averages 52.2 days, which is somewhat shorter than that of the first generation.

TABLE 17.—*Life cycle of the second generation of the codling moth, as observed by rearing, Yakima, Wash., 1919.*

Egg deposition.	Hatching.	Date of—			Days required for—				
		Larvæ leaving fruit.	Pupation.	Emergence of moths.	Incubation.	Feeding of larvæ.	Cocooning.	Pupal period.	Life cycle.
July 15	July 22	Aug. 13	Aug. 18	Aug. 29	7	22	5	11	45
July 18	July 25	Aug. 20	Aug. 26	Sept. 15	7	26	6	20	59
July 20	July 27	Aug. 19	Aug. 28	Sept. 11	7	23	9	14	53
July 22	July 29	...do....	...do....	Sept. 13	7	21	9	16	53
July 27	Aug. 4	Aug. 21	...do....	Sept. 16	8	17	7	19	51
Average					7.2	21.8	7.2	16.0	52.2
Maximum					8	26	9	20	59
Minimum					7	17	5	11	45

THE THIRD GENERATION.

No attempt was made to secure eggs from the few second-brood moths that were reared. Hence no data are available for the third generation.

CODLING-MOTH BAND STUDIES OF 1919.

Owing to the fact that the Yakima Valley is divided into two parts it was considered advisable to keep band records in one orchard in the upper valley and one in the lower valley. The first orchard was inside the city limits of Yakima, about one-fourth mile from the laboratory, and will be spoken of as the Guthrie orchard. In the lower valley an orchard known as the Walden orchard was selected for banding. This is situated about a mile east of Buena and is at the western edge of a large apple district. It is approximately 15 miles southeast of Yakima.

In both orchards burlap bands made of strips of burlap 18 inches wide folded to three thicknesses were applied to the trunks of certain trees and held in place with wire finishing nails. The loose bark had previously been thoroughly scraped from the trees. These bands were examined every three days throughout the season, and the worms found were counted and put into glass jars, where they were

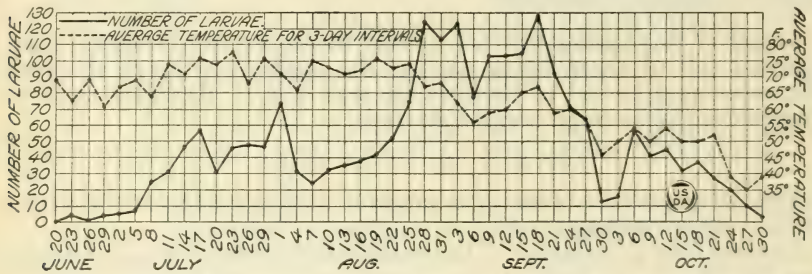


FIG. 9.—Occurrence of codling moth larvæ under bands of apple trees at Yakima, Wash., 1919.

allowed to spin cocoons in strips of corrugated pasteboard, the moths emerging from these cocoons being used in subsequent life-history studies.

In the Guthrie orchard the trees were large, being 25 years old or older. These trees were sprayed, but not efficiently enough to control the worms. Twenty-four trees were banded, and a total of 2,162 larvæ were collected. In Figure 9 will be found the details of these band collections. A distinct break between the first and second broods will be noted, occurring during the first week in August. The maximum for the first brood was 74 larvæ collected on August 1, but it is believed that the true maximum is more nearly represented by the high point of July 17, since the maximum number of larvæ left the fruit in the insectary on July 12. The maximum period of leaving fruit for the second brood occurred August 28 to September 3, and was September 3 at the insectary. A second high point occurred September 18. This was caused by the cool weather of September 3 to 12 slowing up the growth of the larvæ. As soon as the weather became warm again they left the fruit in large numbers.

The trees in the Walden orchard at Buena were 25 years old. Ten trees were banded, seven of them being sprayed and three unsprayed. A total of 5,044 worms was collected from these bands, 2,021 being from the seven sprayed trees and 3,023 from the three

unsprayed trees. The spraying of the trees greatly reduced the total number of worms but had no effect on the time of leaving fruit, the maximum number occurring in both groups of trees on the same day,

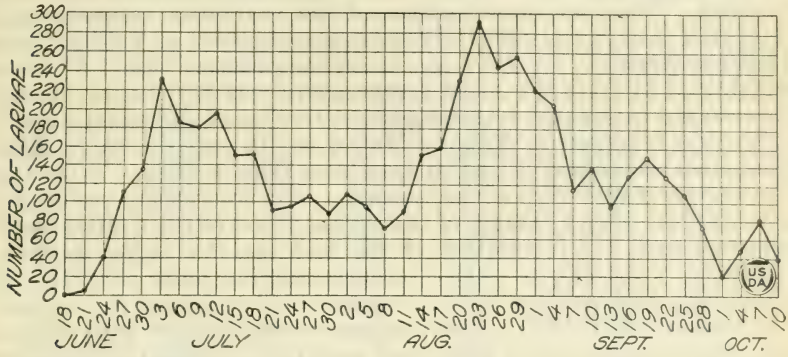


FIG. 10.—Occurrence of codling moth larvæ under bands on apple trees at Buena, Wash., 1919.

August 23. Here, as at Yakima, a definite break occurred between the first and second broods about the 1st of August (fig. 10). The maximum number of first-brood larvæ was collected on July 3, 14

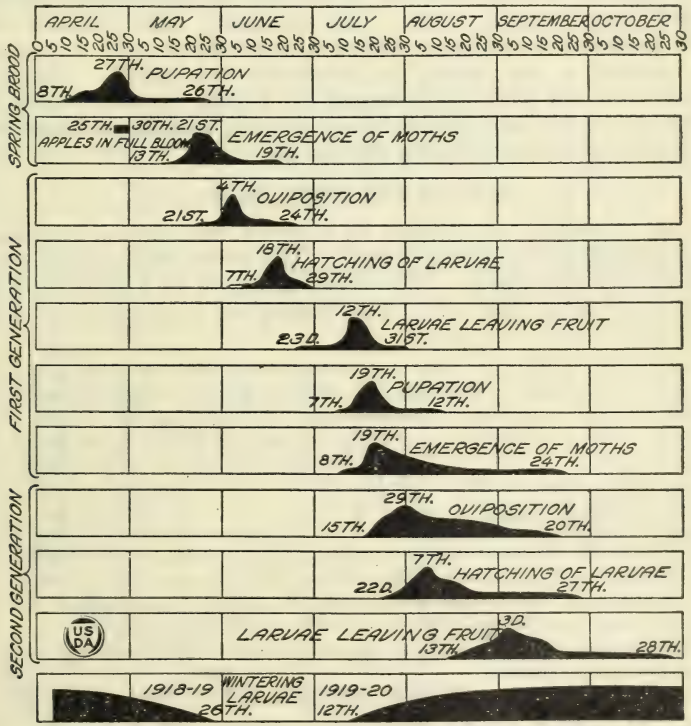


FIG. 11.—Seasonal history of the codling moth at Yakima, Wash., 1919.

days earlier than at Yakima, and the maximum number of second-brood larvæ occurred August 23, five days earlier than at Yakima.

A summary of the seasonal history of the codling moth in 1919 is shown in Figure 11.

SEASONAL-HISTORY STUDIES OF 1920.

The season of 1920 proved to be quite different from that of 1919. According to the Weather Bureau, the spring was the most backward on record. The first three months of the year were about normal, but April was extremely cold, the mean temperature at Yakima being 5.1° below normal. In May the mean temperature was 2.6° below normal, and in June the mean temperature was 2.3° below normal. This resulted in greatly retarding the activities of the codling moth. Apple trees bloomed at Yakima May 6 to 10, and the calyx spray was applied about May 20, or 10 days later than in 1919. After July 1 the temperatures were above normal. The cold spring resulted in slowing up the various stages of the spring brood of the codling moth. Beginning with the incubation of the first brood of eggs, however, the periods were shorter than the corresponding ones of 1919. In spite of this the seasonal history continued throughout the summer to be later than in 1919. The studies recorded below were carried out in the same way as in 1919, and each table should be considered as a unit.

WINTERING LARVÆ.

In order to provide material for the 1920 studies, a large number of wintering larvæ were secured in the fall of 1919 from reared material and from banded trees. The extremely cold weather of December, described on page 58, killed all these larvæ, and it was necessary to collect a new supply in February and March. These were collected wherever they had escaped the freeze, many of them being taken from the soil about the bases of trees and from bands which were covered with snow during the freeze.

PUPÆ OF THE SPRING BROOD.

Time of pupation.—In Figure 12 is given the time of pupation of 160 individuals of the spring brood. The effect of the cold weather in April is very noticeable. Two larvæ pupated on April 3, and there were no more until April 12. The maximum occurred April 26 and

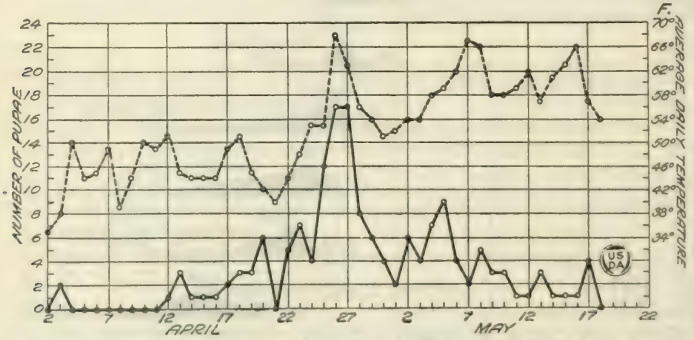


FIG. 12.—Pupation of the spring brood of the codling moth at Yakima, Wash., 1920.

27, however, which is the same time as the maximum for 1919. Pupation ended on May 17, with a single late straggler on June 3.

Length of the pupal stage.—Table 18 shows the length of the pupal stage of 136 pupæ, the average being 33.56 days, two days longer than in 1919.

TABLE 18.—*Length of the pupal stage of pupæ of the spring brood of the codling moth, Yakima, Wash., 1920.*

Date of pupation.	Number of pupæ.	Pupal period in days.			Date of pupation.	Number of pupæ.	Pupal period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
Apr. 3	2	42.00	42	42	Apr. 30	4	33.75	35	33
12	1	36.00	36	36	May 1	2	34.00	34	34
13	3	36.00	37	34	2	4	32.50	34	32
14	1	36.00	36	36	3	4	31.25	32	31
15	1	31.00	31	31	4	5	31.00	31	31
16	1	34.00	34	34	5	5	31.00	31	31
17	2	32.50	33	32	6	3	31.67	32	31
18	2	37.00	37	37	7	1	34.00	34	34
19	3	33.67	37	31	8	3	33.33	35	32
20	6	33.00	35	32	9	2	34.00	34	34
22	5	32.00	34	30	10	2	33.50	34	33
23	7	32.86	35	32	12	1	32.00	32	32
24	3	32.00	32	32	13	3	32.33	34	31
25	11	31.91	36	31	14	1	33.00	33	33
26	14	35.57	38	34	15	1	34.00	34	34
27	15	35.33	37	34	16	1	33.00	33	33
28	8	33.25	37	27	17	3	32.67	33	32
29	6	34.50	35	34					

Total number of pupæ	136
Average length of pupal stage in days	33.56
Maximum length of pupal stage in days	42
Minimum length of pupal stage in days	27

MOTHS OF THE SPRING BROOD.

Time of emergence.—Moths began emerging May 10, but the cold weather held them back, and the maximum period of emergence did not occur until May 25 to June 5, with a maximum of 115 moths on June 2, which was 12 days later than in 1919. Moths continued emerging until July 2. These records will be found in Figure 13.

FIG. 13.—Emergence of the spring brood of moths of the codling moth at Yakima, Wash., 1920.

Oviposition by moths of the spring brood.—Oviposition records were obtained from 824 moths confined in cages of about 25 moths each, and tabulated in Table 19. The averages are cage and not individual averages. (See p. 68 for some individual averages.)

TABLE 19.—*Oviposition by codling moths of the spring brood in rearing cages, Yakima, Wash., 1920.*

Observation.	Number of moths	Sex.		Date of—				Number of days—				Total number of eggs deposited.
		Male.	Female.	Emergence.	First oviposition.	Maximum oviposition.	Last oviposition.	Before oviposition.	From emergence to maximum oviposition.	Of oviposition.	From emergence to last oviposition.	
1	6	1	5	May 15	May 19	May 24	June 8	4	9	21	24	9
2	12	9	3	May 16	May 26	June 19	June 19	10	34	25	34	23
3	9	8	1	May 17	.....	.....	.....	.....	.....	.....	.....	0
4	11	7	4	May 18	May 26	June 3	June 4	8	16	10	17	13
5	8	7	1	May 19	June 11	June 11	June 11	23	23	1	23	5
6	21	13	8	May 20	May 31	May 31	June 8	11	11	9	19	32
7	6	5	1	May 21	.....	.....	.....	.....	.....	.....	.....	0
8	25	12	13	May 22	May 26	June 3	June 13	4	12	19	22	33
9	14	11	3	May 23	May 31	...do.....	June 3	8	11	4	11	4
10	12	11	1	May 24	June 3	June 9	June 12	10	16	10	19	6
11	32	19	13	May 25	May 31	...do.....	June 21	6	15	22	27	177
12	71	29	42	May 26	...do.....	June 3	June 14	5	8	15	19	129
13	48	24	24	May 27	June 1	June 8	...do.....	5	12	14	18	169
14	40	25	15	May 28	...do.....	June 11	June 15	4	14	15	18	59
15	13	5	8	May 29	June 20	June 20	June 25	22	22	6	27	3
16	32	16	16	May 30	June 2	June 8	June 8	3	9	7	9	11
17	75	32	43	May 31	June 3	June 4	June 26	3	4	24	26	53
18	75	26	49	June 1	...do.....	June 18	June 29	2	17	27	28	220
19	50	16	34	June 2	June 4	June 20	...do.....	2	18	26	27	167
20	50	18	32	June 3	...do.....	June 9	June 28	1	6	25	25	374
21	50	16	34	June 4	June 5	June 12	...do.....	1	8	24	24	274
22	29	9	20	June 5	June 8	June 18	...do.....	3	13	21	23	210
23	7	4	3	June 6	June 26	June 26	June 27	20	20	2	21	6
24	14	4	10	June 7	June 12	June 15	June 29	5	8	18	22	194
25	13	5	8	June 8	June 16	June 30	June 30	8	22	15	22	34
26	17	8	9	June 9	June 12	June 15	June 28	3	6	17	19	79
27	26	6	20	June 10	June 13	June 21	June 29	3	11	17	19	31
28	9	5	4	June 11	June 20	June 23	June 25	9	12	6	14	10
29	13	9	4	June 12	June 18	June 27	June 29	6	15	12	17	90
30	12	5	7	June 13	June 17	June 21	July 1	4	8	15	18	267
31	13	4	9	June 16	June 23	June 29	...do.....	7	13	9	15	21
32	11	3	8	June 20	June 26	June 30	July 10	6	10	15	20	68
Average								6.87	13.43	15.03	20.90	.....
Maximum								23	34	27	34	.....
Minimum								1	4	1	9	.....

Number of male moths	372
Number of female moths	452
Total number of moths	824
Total number of eggs	2,771
Average number of eggs per female moth	6.13

Number of eggs per female moth.—Of the moths in these cages, 452 were females. These deposited 2,771 eggs, or an average of 6.13 eggs per female, as shown in Table 19.

Length of life of moths.—Male moths lived an average of 16.65 days; females, 17.73 days. These data are detailed in Table 20. The average life was somewhat longer than in 1919, owing to the cooler weather.

TABLE 20.—*Length of life of male and female codling moths of the spring brood, Yakima, Wash., 1920.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
2	4	2	2	17	18	17	21	32	4	32	0
3	10	3	8	18	15	18	33	33	2	33	3
4	6	4	3	19	12	19	17	34	2	34	1
5	9	5	5	20	12	20	20	35	4	35	1
6	7	6	4	21	11	21	20	36	4	36	0
7	9	7	6	22	11	22	16	37	1	37	0
8	20	8	12	23	4	23	14	38	2	38	0
9	12	9	11	24	16	24	20	39	1	39	0
10	19	10	15	25	10	25	12	40	1	40	0
11	13	11	18	26	8	26	16	41	3	41	0
12	16	12	16	27	4	27	17	43	2	43	0
13	17	13	23	28	5	28	12	45	0	45	2
14	20	14	26	29	6	29	9				
15	26	15	38	30	0	30	3	Total.	368	Total.	455
16	18	16	24	31	4	31	7				

Average length of life of male moths, 16.65 days; female moths, 17.73 days.
Maximum length of life of male moths, 43 days; female moths, 45 days.
Minimum length of life of male moths, 2 days; female moths, 2 days.

THE FIRST GENERATION.

EGGS OF THE FIRST BROOD.

Time of egg deposition.—Spring-brood moths began ovipositing May 12, but owing to cold weather very few eggs were deposited before May 31, as shown in Figure 14. From then on eggs were

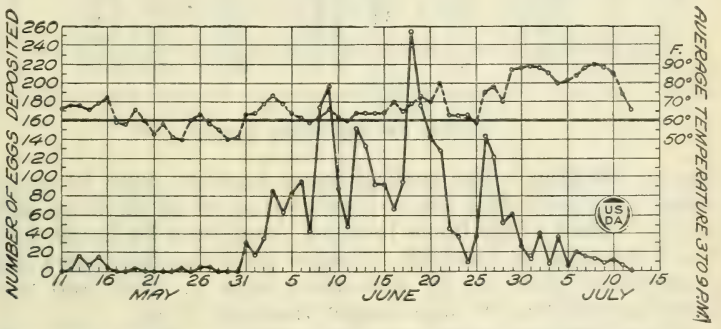


FIG. 14.—Time of deposition of eggs of the first brood of the codling moth at Yakima, Wash., 1920.

deposited daily until July 11, with a maximum on June 18, 14 days later than the 1919 maximum. The temperature curve in Figure 14 shows for each day the average temperature for the period between 3 p. m. and 9 p. m., as this is the period during which most of the eggs are deposited.

Length of incubation.—Observations were made on 1,010 eggs for the length of incubation. These and other data on the development of the eggs are given in Table 21.

TABLE 21.—*Time of deposition and length of incubation of eggs of the first brood of the codling moth, Yakima, Wash., 1920.*

Date of deposition.	Number of eggs.	Number of days from deposition to appearance of—						Incubation period in days.		
		Red ring.			Black spot.					
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
May 31	8	4.00	4	4	9.00	9	9	12.13	13	12
June 1	3	4.00	4	4	10.00	10	10	12.33	13	12
3	5	4.00	4	4	11.00	11	11	13.20	14	13
4	12	5.00	5	5	12.00	12	12	14.75	15	14
5	27	5.00	5	5	11.30	12	11	13.30	14	12
6	59	5.00	5	5	11.00	11	11	13.07	14	13
7	19	6.00	6	6	11.00	11	11	12.60	13	12
8	108	5.10	6	5	10.10	11	10	12.19	14	12
9	104	5.00	5	5	10.00	10	10	11.61	12	11
10	39	5.00	5	5	10.00	10	10	11.00	11	11
11	4	5.00	5	5	9.00	9	9	10.75	11	10
12	28	5.00	5	5	9.00	9	9	10.25	11	10
13	46	5.00	5	5	8.20	9	8	11.04	12	10
14	18	4.00	4	4	8.11	9	8	11.00	12	10
15	55	4.00	4	4	8.07	9	8	11.00	12	10
16	35	4.00	4	4	8.00	8	8	10.89	11	10
17	34	3.00	3	3	8.18	11	8	11.24	13	11
18	175	3.00	3	3	9.04	10	9	10.17	12	10
19	31	4.00	4	4	9.16	10	9	10.35	12	10
20	61	3.00	3	3	8.02	9	8	9.54	11	9
21	23	5.00	5	5	8.00	8	8	9.30	10	9
22	1	5.00	5	5	8.00	8	8	9.00	9	9
24	3	5.00	5	5	6.00	6	6	7.33	8	7
25	5	4.00	4	4	6.00	6	6	7.20	8	7
26	28	4.00	4	4	5.00	5	5	6.36	7	6
27	13	4.00	4	4	5.00	5	5	6.00	6	6
28	4	4.00	4	4	5.00	5	5	6.25	7	6
29	10	3.00	3	3	4.00	4	4	6.20	7	6
30	2	3.00	3	3	4.00	4	4	6.50	7	6
July 1	1	3.00	3	3	5.00	5	5	6.00	6	6
2	25	2.00	2	2	4.00	4	4	6.04	7	6
3	3	2.00	2	2	5.00	5	5	6.00	6	6
4	18	4.00	4	4	5.00	5	5	6.06	7	6
6	5	3.00	3	3	4.80	5	4	5.80	6	5
7	7	4.00	4	4	5.57	6	5	7.00	7	7
	1,010	4.14	6	2	8.75	12	4	10.60	15	5

LARVÆ OF THE FIRST BROOD.

Time of hatching.—The earliest larvæ hatched June 12 and hatching continued until July 14, a total period of 33 days, as shown in Figure 15. Most of the larvæ hatched from June 19 to 29, inclusive, with a maximum on June 28, 16 days after the first larva hatched. The maximum occurred 10 days later than in 1919, and the total hatching period was 10 days longer than in 1919.

Length of feeding period, stock-jar method.—The average feeding period of 268 larvæ (both transforming and nontransforming) by the stock-jar method was 19.05 days. (See Table 22.)

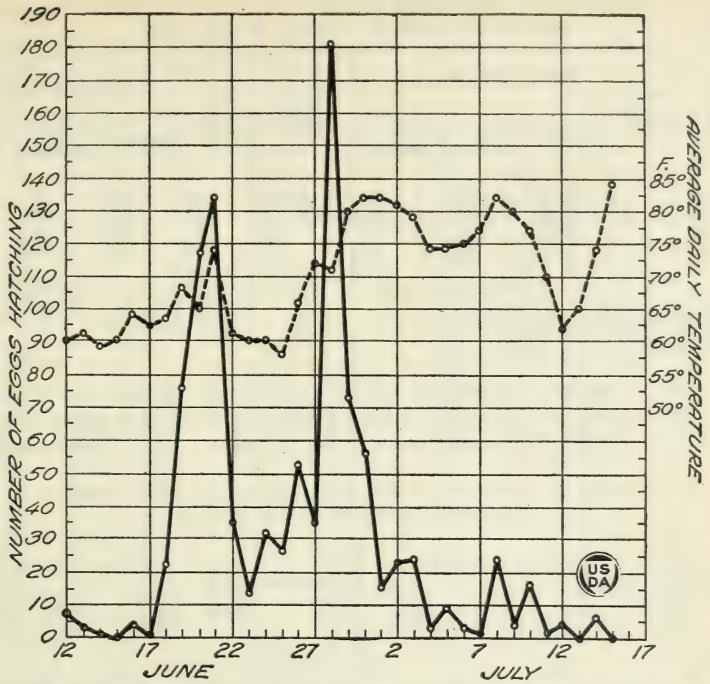


FIG. 15.—Hatching of larvæ of the first brood of the codling moth at Yakima, Wash., 1920.

TABLE 22.—*Length of feeding period of larvæ of the first brood of the codling moth, stock-jar method, Yakima, Wash., 1920.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
June 18	2	20.00	20	20	July 3	22	20.41	30	10
19	1	17.00	17	17	4	18	18.11	22	11
20	14	20.29	30	17	5	16	19.06	26	13
21	10	20.20	24	17	6	11	19.73	31	12
22	7	19.71	24	17	7	7	17.71	20	16
23	6	18.83	23	16	8	6	21.50	25	19
24	8	17.50	20	15	9	12	21.33	26	17
25	4	16.00	17	15	10	14	20.36	23	18
26	15	18.60	24	15	11	6	17.83	21	14
27	13	17.54	22	13	12	2	16.50	17	16
28	7	18.29	20	16	13	1	21.00	21	21
29	18	17.72	23	14	14	7	21.29	33	17
30	12	16.83	20	14	15	3	20.67	27	17
July 1	12	16.83	19	15	16	2	16.00	16	16
2	10	21.30	29	16	17	2	21.00	22	20

Total number of larvæ	268
Average length of feeding period in days	19.05
Maximum length of feeding period in days	33
Minimum length of feeding period in days	10

Length of feeding period, bagged-fruit method.—Where the bagged-fruit method of feeding was used, the average period was 20.28 days. (See Table 23.)

TABLE 23.—*Length of feeding period of larvæ of the first brood of the codling moth, bagged-fruit method, Yakima, Wash., 1920.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
June 24	9	21.22	26	18	June 30	4	17.25	20	15
26	5	19.00	23	16	July 1	14	21.57	28	17
27	3	20.00	26	15	2	4	20.50	24	18
28	4	18.25	19	17	3	4	22.25	24	20
29	10	19.50	24	14					

Total number of larvæ	57
Average length of feeding period in days	20.28
Maximum length of feeding period in days	28
Minimum length of feeding period in days	14

Length of cocooning period.—The cocooning period, or the total period from the time the larva leaves the fruit until it pupates, averaged 5.48 days for 235 transforming individuals. (See Table 24.)

TABLE 24.—*Length of cocooning period of transforming codling moth larvæ of the first brood, Yakima, Wash., 1920.*

Larvæ left fruit.	Number of larvæ.	Cocooning period in days.			Larvæ left fruit.	Number of larvæ.	Cocooning period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 6	1	4.00	4	4	July 24	4	5.00	7	4
7	3	4.33	5	4	25	8	7.00	15	4
8	4	5.25	7	4	26	5	6.40	14	4
9	7	5.57	6	5	27	6	6.50	13	4
10	11	5.55	7	5	28	3	6.33	8	5
11	12	5.42	6	5	29	6	5.17	8	4
12	9	5.11	6	4	30	4	5.50	8	3
13	16	4.13	5	4	31	3	4.00	4	4
14	8	4.63	8	4	Aug. 1	5	5.60	11	4
15	14	5.29	15	3	2	3	4.33	5	4
16	14	4.86	7	4	3	1	5.00	5	5
17	10	4.60	6	3	4	1	10.00	10	10
18	20	5.55	9	3	6	1	4.00	4	4
19	16	6.31	16	4	7	1	5.00	5	5
20	11	6.18	10	5	11	1	4.00	4	4
21	10	5.70	7	4					
22	6	5.83	10	4	Total.	235	5.48	22	3
23	11	6.91	22	4					

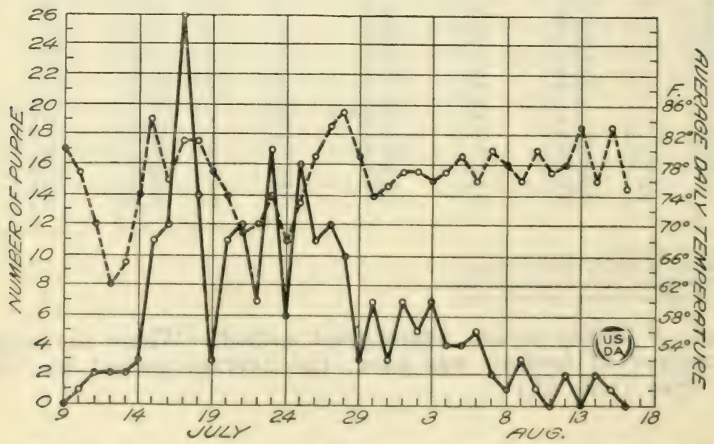


FIG. 16.—Pupation of the first brood of the codling moth at Yakima, Wash., 1920.

PUPÆ OF THE FIRST BROOD.

Time of pupation.—The first pupa occurred July 10, and larvæ continued to pupate until August 15, with a maximum on July 17, as shown in Figure 16.

Length of pupal stage.—The average length of the pupal stage of 219 pupæ was 12.37 days, as shown in Table 25.

TABLE 25.—*Length of the pupal stage of pupæ of the first brood of the codling moth, Yakima, Wash., 1920.*

Date of pupation.	Number of pupæ.	Pupal period in days.			Date of pupation.	Number of pupæ.	Pupal period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 10	1	13.00	13	13	July 27	11	11.82	13	11
11	2	14.00	14	14	28	10	12.20	13	11
12	2	12.50	13	12	29	3	12.00	13	11
13	2	13.00	13	13	30	7	12.71	16	12
14	3	12.00	12	12	31	3	11.00	11	11
15	11	12.45	14	12	Aug. 1	7	10.86	13	7
16	11	12.82	14	11	2	4	11.50	12	11
17	25	12.56	14	11	3	7	11.57	12	11
18	12	12.17	14	11	4	4	12.00	12	12
19	3	12.67	14	12	5	4	11.75	14	11
20	11	13.18	14	11	6	4	13.75	14	13
21	10	12.70	13	11	7	1	12.00	12	12
22	6	12.00	13	11	8	1	15.00	15	15
23	17	11.82	13	10	9	1	13.00	13	13
24	6	11.83	13	11	10	1	14.00	14	14
25	14	12.21	14	11	12	2	17.50	19	16
26	11	11.82	13	11	14	2	18.50	20	17

Total number of pupæ	219
Average length of the pupal stage in days	12.37
Maximum length of the pupal stage in days	20
Minimum length of the pupal stage in days	7

MOTHS OF THE FIRST BROOD.

Time of emergence.—Moths began emerging July 23 and continued until September 30, the maximum occurring on August 15, although the maximum period of emergence extended from July 27 to August 24. (See fig. 17.) This is about 10 days later than the maximum period for 1919.

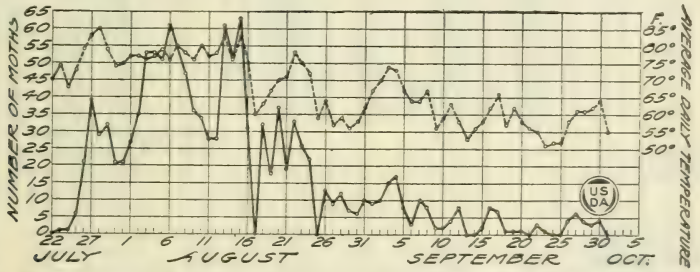


FIG. 17.—Emergence of the first brood of moths of the codling moth at Yakima, Wash., 1920

Oviposition by moths of the first brood.—A total of 1,076 moths was used in obtaining oviposition records, the first of these emerging July 27. Many of these moths began ovipositing the day following emergence. The interval before maximum oviposition was 67.0 days. This is shown in Table 26, the averages being for cages and not individuals.

Number of eggs per female moth.—Table 26 shows that 620 females deposited 13,615 eggs.

TABLE 26.—*Oviposition by codling moths of the first brood in rearing cages, Yakima, Wash., 1920.*

Observation.	Number of moths.	Sex.		Date of—				Number of days—				Total number of eggs deposited.
		Male.	Female.	Emergence.	First oviposition.	Maximum oviposition.	Last oviposition.	Before oviposition.	From emergence to maximum oviposition.	Of oviposition.	From emergence to last oviposition.	
1	38	10	28	July 27	July 28	Aug. 3	Aug. 13	1	7	17	17	1,067
2	28	10	18	July 28	July 29	Aug. 2	Aug. 17	1	5	20	20	978
3	30	18	12	July 29	July 30	Aug. 7	Aug. 13	1	9	15	15	868
4	19	10	9	July 30	Aug. 1	Aug. 5	Aug. 16	2	6	16	17	654
5	18	6	12	July 31	Aug. 2	Aug. 4	Aug. 13	2	4	12	13	925
6	25	7	18	Aug. 1	...do.....	Aug. 3	Aug. 10	1	2	9	9	72
7	25	10	15	Aug. 2	Aug. 3	...do.....	Aug. 13	1	1	11	11	217
8	51	16	35	Aug. 3	Aug. 4	Aug. 6	Aug. 15	1	3	12	12	813
9	51	23	28	Aug. 4	Aug. 5	...do.....	Aug. 20	1	2	16	16	639
10	51	23	28	Aug. 5	Aug. 6	Aug. 7	Aug. 21	1	2	16	16	484
11	62	29	33	Aug. 6	Aug. 7	Aug. 9	Aug. 20	1	3	14	14	781
12	52	24	28	Aug. 7	Aug. 8	...do.....	Aug. 23	1	2	16	16	575
13	45	20	25	Aug. 8	Aug. 9	Aug. 12	Aug. 22	1	4	14	14	303
14	36	13	23	Aug. 9	Aug. 11	Aug. 15	Aug. 23	2	6	13	14	407
15	27	13	14	Aug. 10	...do.....	Aug. 14	Aug. 26	1	4	16	16	460
16	18	8	10	Aug. 11	Aug. 13	...do.....	Sept. 1	2	3	20	21	343
17	26	10	16	Aug. 12	Aug. 14	Aug. 22	...do.....	2	10	19	20	49
18	55	24	31	Aug. 13	...do.....	Aug. 15	Aug. 31	1	2	18	18	318
19	45	18	27	Aug. 14	Aug. 15	Aug. 24	Sept. 1	1	10	18	18	360
20	57	22	35	Aug. 15	Aug. 16	Aug. 22	Sept. 2	1	7	18	18	170
21	24	12	12	Aug. 18	Aug. 21	Aug. 23	Sept. 5	3	5	16	18	303
22	25	9	6	Aug. 19	Aug. 22	...do.....	Sept. 8	3	4	18	20	173
23	15	12	13	Aug. 20	...do.....	...do.....	Sept. 6	2	3	16	17	428
24	29	6	13	Aug. 21	Aug. 23	Sept. 2	Sept. 4	2	12	13	14	29
25	12	17	15	Aug. 22	...do.....	Aug. 23	Sept. 10	1	1	19	19	244
26	35	12	13	Aug. 23	Aug. 26	Aug. 26	Sept. 8	3	3	14	16	176
27	21	9	12	Aug. 24	Aug. 31	Sept. 2	Sept. 19	7	9	20	26	115
28	23	5	8	Aug. 26	Aug. 30	...do.....	Sept. 17	4	7	19	22	31
29	19	3	6	Aug. 27	Sept. 1	Sept. 3	Sept. 15	5	7	15	19	162
30	11	6	5	Aug. 28	Sept. 2	Sept. 7	Sept. 12	5	10	11	15	121
31	8	3	5	Aug. 29	Sept. 3	Sept. 4	Sept. 7	5	6	5	9	17
32	6	1	5	Aug. 30	Sept. 4	Sept. 16	Sept. 28	5	17	25	29	65
33	8	3	5	Aug. 31	Sept. 3	Sept. 10	Sept. 21	3	10	19	21	113
34	9	4	5	Sept. 1	Sept. 4	Sept. 4	Sept. 17	3	3	14	16	285
35	9	4	5	Sept. 2	...do.....	...do.....	Sept. 18	2	2	15	16	5
36	14	4	10	Sept. 3	...do.....	Sept. 6	Sept. 29	1	3	26	26	179
37	17	10	7	Sept. 4	Sept. 7	Sept. 10	Sept. 24	3	6	18	20	100
38	8	3	5	Sept. 5	...do.....	Sept. 16	Sept. 20	2	11	14	15	34
39	3	1	2	Sept. 6	Sept. 16	...do.....	Sept. 26	10	10	11	20	66
40	10	5	5	Sept. 7	Sept. 12	Sept. 14	Sept. 27	5	7	16	20	96
41	8	5	3	Sept. 8	Sept. 9	Sept. 12	Oct. 1	1	4	23	23	246
42	8	3	5	Sept. 12	Sept. 16	Sept. 18	Sept. 30	4	6	15	18	97
43	8	4	4	Sept. 16	Sept. 30	Oct. 4	Oct. 8	14	18	9	22	40
44	7	1	6	Sept. 17	Sept. 28	Sept. 28	Oct. 7	11	11	10	20	7
Average								2.93	6.07	15.70	17.64	.....
Maximum								14	18	26	29	.....
Minimum								1	1	5	9	.....

Number of male moths	456
Number of female moths	620
Total number of moths	1,076
Total number of eggs	13,615
Average number of eggs per female moth	21.96

Length of life of moths.—Male moths lived an average of 13.87 days; females, 13.24 days. These data are given in Table 27.

TABLE 27.—*Length of life of male and female codling moths of the first brood, Yakima, Wash., 1920.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
1	0	1	2	14	21	14	21	27	7	27	0
2	5	2	7	15	25	15	30	28	4	28	3
3	6	3	16	16	21	16	30	29	3	29	2
4	6	4	17	17	16	17	20	30	1	30	3
5	20	5	31	18	15	18	31	31	1	31	1
6	14	6	22	19	9	19	15	32	2	32	2
7	14	7	29	20	16	20	16	34	1	34	2
8	26	8	21	21	20	21	23	35	0	35	1
9	23	9	28	22	8	22	8	38	0	38	1
10	22	10	28	23	7	23	9	39	0	39	1
11	20	11	41	24	5	24	9	40	0	40	1
12	18	12	28	25	2	25	5				
13	27	13	35	26	6	26	7	Total.	391	Total.	546

Average length of life of male moths, 13.87 days; female moths, 13.24 days.
Maximum length of life of male moths, 34 days; female moths, 40 days.
Minimum length of life of male moths, 2 days; female moths, 1 day.

LIFE CYCLE OF THE FIRST GENERATION.

Life-cycle, stock-jar feeding method.—Table 28 gives the life cycle of 177 individuals of the first generation, all of which were reared from egg to moth, the larvæ being fed by the stock-jar method. The incubation period averaged 8.98 days, the larval feeding period 18.21 days, the cocooning period 5.44 days, the pupal period 12.45 days, and the life cycle 45.08 days. To this must be added 2.93 days, which is the average interval between emergence of the first-brood moth and egg deposition, in order to obtain the complete life cycle from deposition of first-brood egg to deposition of second-brood egg. This gives a complete life cycle of 48.01 days.

TABLE 28.—*Life cycle of the first generation of the codling moth as observed by rearing, stock-jar feeding method, Yakima, Wash., 1920.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.[1]		
			Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
		Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
June 5	2	13	20.00	20	20	6.00	7	5	12.50	13	12	51.50	52	51
6	1	13	17.00	17	17	4.00	4	4	13.00	13	13	47.00	47	47
8	12	12	20.33	30	17	4.75	6	4	12.83	14	12	49.91	59	47
9	9	12	20.00	24	17	5.22	7	3	12.67	14	11	49.89	55	47
12	6	10	20.00	24	17	4.83	6	4	12.50	13	12	47.33	52	44
13	6	10	18.83	23	16	5.17	6	4	12.83	14	12	46.83	51	43
13	7	11	17.14	20	15	5.14	7	4	12.00	13	11	45.28	47	44
14	4	11	16.00	17	15	5.25	6	5	13.25	14	13	45.50	46	45
15	11	11	18.45	24	15	5.09	6	3	13.18	14	12	47.72	54	44
16	9	11	17.44	22	13	4.89	6	4	12.44	14	11	45.77	52	41
18	6	10	18.00	20	16	5.00	7	4	12.33	13	11	45.33	49	42
19	11	10	17.09	23	14	4.73	6	4	12.82	14	11	44.64	51	39
20	8	10	16.75	20	14	5.13	7	3	12.13	13	11	44.01	48	40
21	9	10	16.56	18	15	6.44	16	4	11.89	13	11	44.89	56	42
26	4	6	20.25	28	16	4.75	7	3	12.00	13	11	43.00	48	40
26	15	7	18.87	29	10	6.27	11	4	12.33	16	11	44.47	54	32
28	12	6	16.83	22	11	7.83	22	4	12.83	20	11	43.49	67	33
29	7	6	16.71	24	13	5.29	7	4	11.14	12	9	39.14	46	34
29	9	7	18.44	31	12	5.56	8	4	11.89	14	11	42.89	56	37
30	5	7	17.20	19	16	4.40	5	4	11.40	12	11	40.00	42	38
July 2	2	6	20.50	22	19	4.50	5	4	12.50	13	12	43.50	44	43
3	3	6	21.33	26	17	7.00	10	4	14.00	17	12	48.33	59	39
4	5	6	19.60	23	18	5.60	8	4	11.80	14	11	43.00	47	40
4	4	7	17.25	21	14	6.75	11	4	11.50	16	7	42.50	55	35
6	1	6	17.00	17	17	5.00	5	5	12.00	12	12	40.00	40	40
6	1	7	21.00	21	21	5.00	5	5	15.00	15	15	48.00	48	48
7	4	7	18.75	24	17	4.25	5	4	13.75	19	12	43.75	55	40
8	2	7	17.50	18	17	4.50	5	4	14.00	14	14	43.00	43	43
9	2	7	16.00	16	16	4.00	4	4	11.00	11	11	38.00	38	38
	177	[2]8.98	18.21	31	10	5.44	22	3	12.45	20	7	45.08	67	32

[1] Add 2.93 days for complete life cycle.

[2] Average.

Life cycle, bagged-fruit feeding method.—The life cycle of 43 individuals fed by the bagged-fruit method is given in Table 29. Here the incubation period averaged 9.79 days, the larval feeding period 19.58 days, the cocooning period 5.18 days, the pupal period 12.02 days, and the life cycle 46.57 days, or, adding 2.93 days for the interval between emergence of the moth and egg deposition, 49.50 days for the complete life cycle.

TABLE 29.—*Life cycle of the first generation of the codling moth as observed by rearing, bagged-fruit feeding method, Yakima, Wash., 1920.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.[1]		
			Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
		Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
June 13	4	11	20.00	21	18	8.75	15	5	12.25	13	11	52.00	60	47
15	5	11	19.00	23	16	5.00	6	4	12.00	14	11	47.00	52	43
16	3	11	20.00	26	15	5.00	5	5	13.00	13	13	49.00	55	44
18	3	10	18.33	19	17	3.66	4	3	12.00	13	11	43.99	46	42
19	7	10	18.57	22	14	5.14	9	4	12.00	14	11	45.71	49	39
20	3	10	16.33	17	15	3.33	4	3	12.00	13	11	41.66	43	41
21	11	10	20.55	26	17	5.45	8	5	11.64	13	11	47.64	53	43
25	3	7	19.33	21	18	5.00	5	5	12.33	13	12	43.66	46	42
26	4	7	22.25	24	20	4.00	4	4	12.00	13	11	45.25	47	42
	43	9.79	19.58	26	14	5.18	15	3	12.02	14	11	46.57	60	39

[1] Add 2.93 days for complete life cycle.

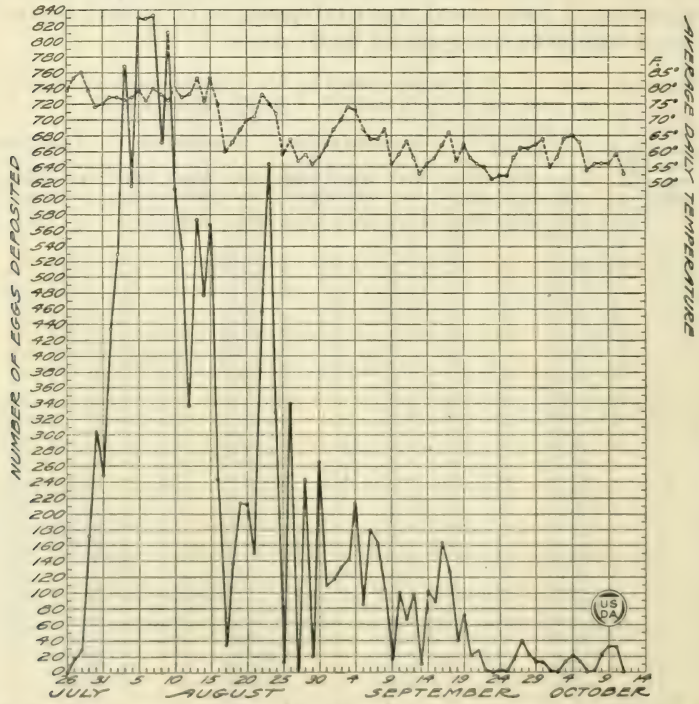


FIG. 18.—Time of deposition of eggs of the second brood of the codling moth at Yakima, Wash., 1920.

THE SECOND GENERATION.

EGGS OF THE SECOND BROOD.

Time of deposition.—The earliest second-brood eggs were deposited July 27, and eggs were deposited almost continuously thereafter until October 10, with a maximum period of oviposition extending practically throughout the month of August, as shown in Figure 18. The actual maximum of 833 eggs occurred on August 7, only 11 days after the first egg was deposited.

Length of incubation.—The incubation period for 4,135 eggs was determined and the data on the various changes in the eggs are shown in Table 30. It will be seen that the average length of incubation was 8.74 days, closely approximating that of 1919.

TABLE 30.—*Time of deposition and length of incubation of eggs of the second brood of the codling moth, Yakima, Wash., 1920.*

Date of deposition.	Number of eggs.	Number of days from deposition to appearance of—						Incubation period in days.		
		Red ring.			Black spot.					
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
July 27	4	3.00	3	3	5.00	5	5	6.00	6	6
28	9	4.00	4	4	5.00	5	5	6.00	6	6
29	21	3.00	3	3	5.00	5	5	6.14	7	6
30	101	2.00	2	2	5.00	5	5	6.43	7	6
31	34	3.00	3	3	5.00	5	5	6.09	7	6
Aug. 1	119	3.00	3	3	5.00	5	5	6.45	8	6
2	148	2.00	2	2	5.00	5	5	6.02	7	6
3	115	2.00	2	2	5.00	5	5	6.00	6	6
4	150	3.00	3	3	5.00	5	5	6.00	6	6
5	139	3.00	3	3	5.00	5	5	6.06	7	6
6	230	2.00	2	2	5.00	5	5	6.00	6	6
7	268	3.00	3	3	5.00	5	5	6.08	7	6
8	237	3.00	3	3	5.00	5	5	6.06	7	6
9	282	3.00	3	3	5.00	5	5	6.02	7	6
10	159	2.00	2	2	5.00	5	5	6.00	6	6
11	82	3.00	3	3	4.00	4	4	6.85	7	5
12	60	3.00	3	3	4.00	4	4	6.67	8	6
13	132	4.00	4	4	6.00	6	6	7.95	8	7
14	111	3.00	3	3	6.00	6	6	8.14	9	7
15	274	3.00	3	3	7.00	7	7	8.00	8	8
16	56	4.93	6	4	7.00	7	7	8.46	9	8
17	1	4.00	4	4	6.00	6	6	7.00	7	7
18	22	4.00	4	4	6.00	6	6	8.50	9	8
19	44	3.02	4	3	6.93	8	6	8.93	10	8
20	82	4.00	4	4	7.78	8	7	10.78	11	10
21	21	3.19	4	3	8.10	9	7	11.05	12	9
22	28	3.07	4	3	8.71	10	8	11.71	13	11
23	237	3.00	3	3	10.00	10	10	12.03	13	12
24	110	4.00	4	4	11.00	11	11	12.00	12	12
26	126	4.00	4	4	9.00	9	9	10.75	11	10
28	134	5.00	5	5	8.03	9	8	10.31	12	10
29	6	3.00	3	3	8.00	8	8	9.17	10	9
30	70	3.00	3	3	8.03	9	8	9.34	11	9
31	14	3.07	4	3	7.79	9	7	9.79	11	9
Sept. 1	19	3.00	3	3	8.05	9	8	10.79	12	10
2	16	4.81	5	4	8.81	9	8	11.75	12	10
3	32	3.00	3	3	11.00	11	11	14.06	15	14
4	100	3.12	4	3	13.12	14	13	14.84	16	14
5	19	4.00	4	4	13.00	13	13	14.92	15	14
6	17	4.00	4	4	13.00	13	13	15.82	17	15
7	80	4.53	5	4	14.53	15	14	18.78	20	17
8	19	4.21	5	4	14.21	15	14	18.00	19	17
10	31	5.00	5	5	15.29	16	15	19.23	20	18
11	23	4.09	5	4	16.43	17	16	18.52	20	18
12	5	4.60	5	4	16.00	16	16	19.00	20	18
13	1	4.00	4	4	16.00	16	16	18.00	18	18
14	20	4.15	5	4	15.85	16	15	18.00	19	17
15	27	4.96	5	4	15.19	16	14	19.19	20	18
16	43	5.05	6	5	15.26	16	15	18.30	20	18
17	40	6.30	7	5	15.65	16	15	18.88	20	18
19	6	4.83	5	4	15.50	16	15	17.50	19	16
20	2	7.00	7	7	16.00	16	16	21.00	21	21
21	9	8.22	9	8	17.22	18	17	21.00	22	20
	4,135	3.19	9	2	7.14	18	4	8.74	22	5

LARVÆ OF THE SECOND BROOD.

Time of hatching.—Second-brood larvæ were hatching during a period of over 10 weeks, beginning August 2 and ending October 13. The maximum period of hatching extended from August 6 to September 6, with an actual maximum on August 12, as shown in Figure 19.

Length of feeding period, stock-jar method.—Table 31 shows the average feeding period of 594 larvæ reared by the stock-jar method.

TABLE 31.—*Length of feeding period of larvæ of the second brood of the codling moth, stock-jar method, Yakima, Wash., 1920.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
Aug. 3	3	22.33	25	17	Aug. 21	20	42.05	68	29
4	6	19.50	21	17	22	22	39.36	60	25
5	14	24.14	33	17	23	27	44.11	65	25
6	30	26.73	44	17	24	23	44.13	63	24
7	12	26.08	36	20	25	10	45.10	61	31
8	35	29.43	49	18	26	15	37.13	48	22
9	53	30.21	60	20	27	4	43.75	61	32
10	43	29.63	54	18	28	5	40.60	59	33
11	39	34.59	70	22	29	1	41.00	41	41
12	29	28.00	48	23	30	6	40.17	53	33
13	28	36.36	70	24	31	7	44.14	57	30
14	38	35.11	64	18	Sept. 1	3	47.00	56	29
15	22	37.68	51	22	2	4	46.00	53	35
16	20	35.70	55	18	3	11	48.55	57	35
17	9	39.22	49	27	4	3	50.67	54	48
18	8	41.38	71	29	5	11	50.00	62	40
19	12	31.83	43	26	6	3	49.33	54	44
20	17	38.71	59	28	8	1	48.00	48	48

Total number of larvæ	594
Average length of feeding period in days	35.30
Maximum length of feeding period in days	71
Minimum length of feeding period in days	17

Length of feeding period, bagged-fruit method.—In Table 32 will be found the feeding period of 106 larvæ reared by the bagged-fruit method.

Owing to the late season, none of the second-brood larvæ reared in 1920 pupated, hence it is not possible to give any further data for this year.

TABLE 32.—*Length of feeding period of larvæ of the second brood of the codling moth, bagged-fruit method, Yakima, Wash., 1920.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
Aug. 7	6	34.17	60	23	Aug. 13	9	36.11	46	27
8	8	33.00	42	26	14	5	44.40	70	25
9	10	33.00	43	25	15	15	43.80	79	32
10	5	31.80	37	23	16	6	46.67	68	34
11	9	36.22	54	26	17	11	45.73	63	21
12	6	33.33	43	25	18	16	49.50	69	37

Total number of larvæ	106
Average length of feeding period in days	40.22
Maximum length of feeding period in days	79
Minimum length of feeding period in days	21

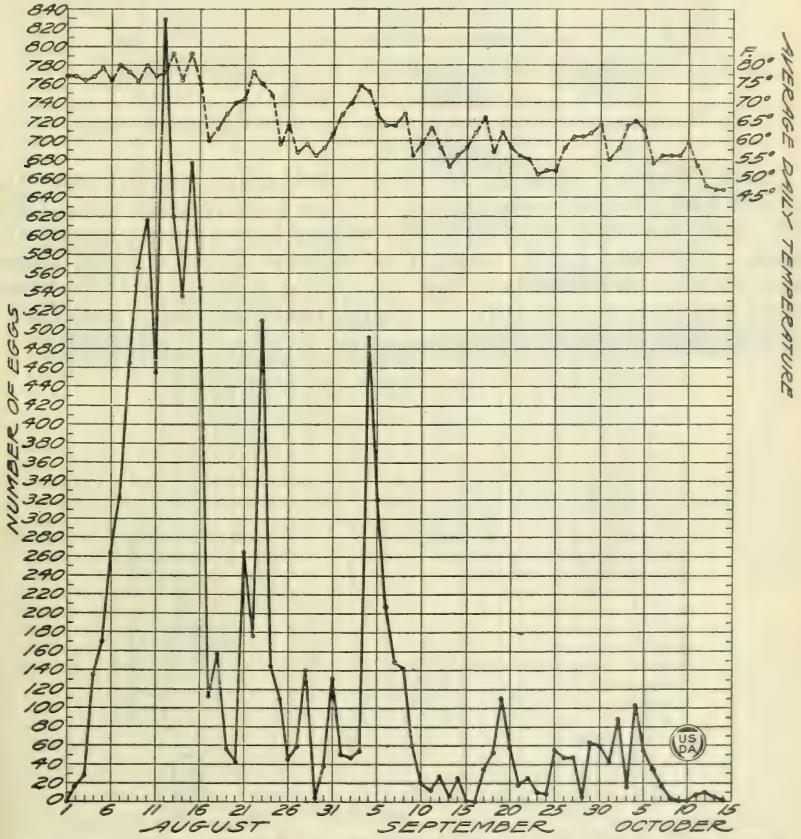


FIG. 19.—Hatching of larvæ of the second brood of the codling moth at Yakima, Wash., 1920.

CODLING-MOTH BAND STUDIES OF 1920.

In 1920 trees were again banded in both the Guthrie orchard at Yakima and the Walden orchard near Buena, the larvæ being collected every three days, as in 1919. In the Guthrie orchard, 29 trees were banded, and although these trees were sprayed and

there was a high winter mortality, 5,347 worms were secured, more than twice as many as in 1919. The first worms appeared in the bands on July 8, 15 days later than in 1919, and the maximum for the first brood occurred July 20. The number decreased thereafter until August 19, after which it rose, reaching a maximum for the second brood on September 6, as shown in Figure 20.

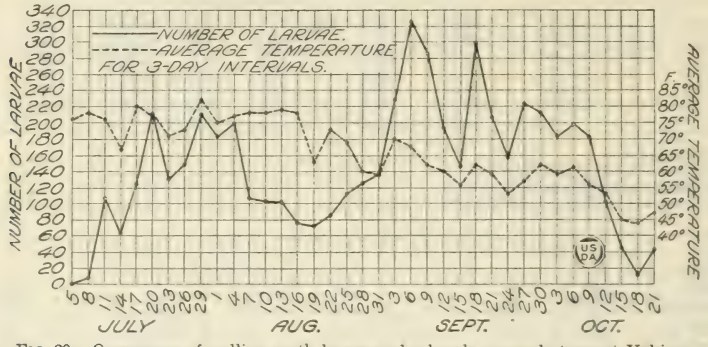


FIG. 20.—Occurrence of codling moth larvæ under bands on apple trees at Yakima, Wash., 1920.

In the Walden orchard, 10 trees were again banded, but the orchard had changed owners, and was very thoroughly sprayed in 1920, with the result that only 665 worms were secured during the season. This was hardly enough to indicate the maximum occurrence of the two broods. The maximum number of first-brood worms was collected on July 17, though nearly as many were found

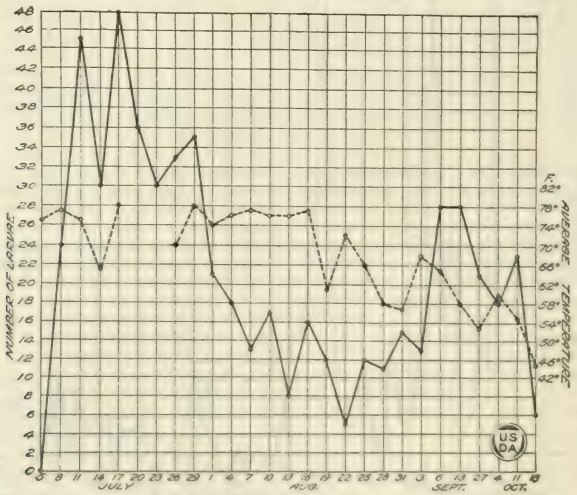


FIG. 21.—Occurrence of codling moth larvæ under bands on apple trees at Buena, Wash., 1920.

on July 11, which is 9 days earlier than the maximum at Yakima. For the second brood, the maximum was not obtained until September 6, the same date as the maximum at Yakima, as shown in Figure 21.

A summary of the seasonal history of the codling moth for 1920 is shown in Figure 22.

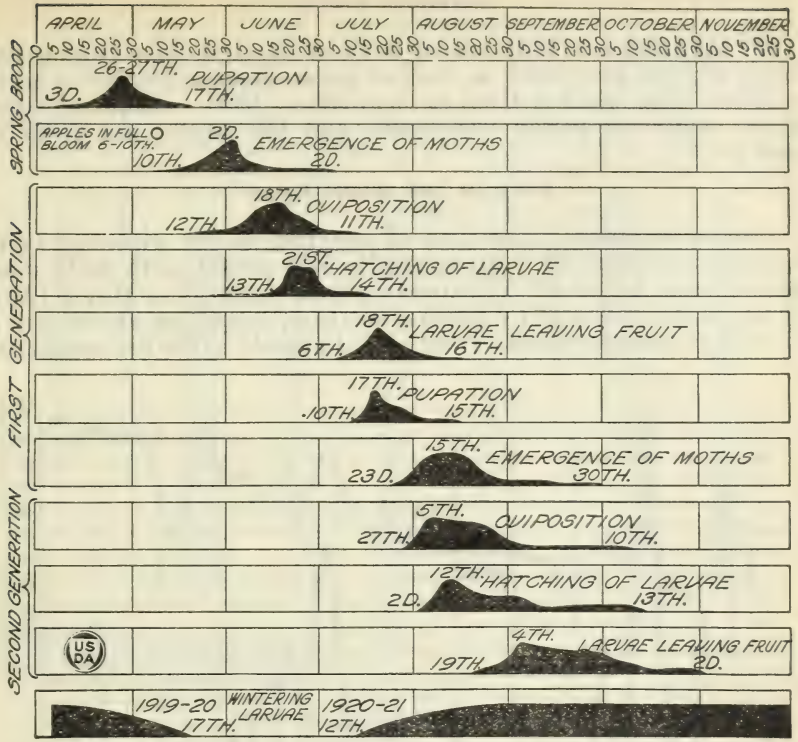


FIG. 22.—Seasonal history of the codling moth at Yakima, Wash., 1920.

SEASONAL HISTORY STUDIES OF 1921.

The life-history studies of the codling moth were continued in 1921 in much the same manner as in the two previous seasons, and considerably more material was handled, especially in the studies of the spring brood. Complete data on wintering larvæ were obtained for the first time. No third-brood larvæ were hatched in the insectary.

The development of the codling moth corresponded closely to that of 1919. Minimum temperatures of 26° and 29° F. on April 24 and 30, respectively, delayed the blooming period of apples so as to extend it over the period from April 26 to May 7. These abnormally low temperatures froze many blossoms, but did not cause a noticeable loss in the apple production of the valley. However, pupal development of the spring brood was interrupted, and two periods of pupation resulted. High temperatures during the time from May 30 to June 6 greatly hastened the development of the codling moth, and many orchardists were late in applying the first cover spray. The remainder of the growing season was favorable and the precipitation was only slightly below normal.

WINTERING LARVÆ.

For the studies of 1921, reared larvæ of the first and second generations of 1920 were used, as well as a considerable number of larvæ collected from banded trees in September, 1920. A special study of the wintering period was made, and the results are given on page 59.

PUPÆ OF THE SPRING BROOD.

Time of pupation.—The time of pupation of 732 wintering larvæ is shown in Figure 23. An unusually cold period, with daily mean temperatures below 50° F. extending from April 22 to May 3 (April 28 excepted), followed by warmer weather, caused an abundance of larvæ to pupate at two widely separated periods. The first maximum

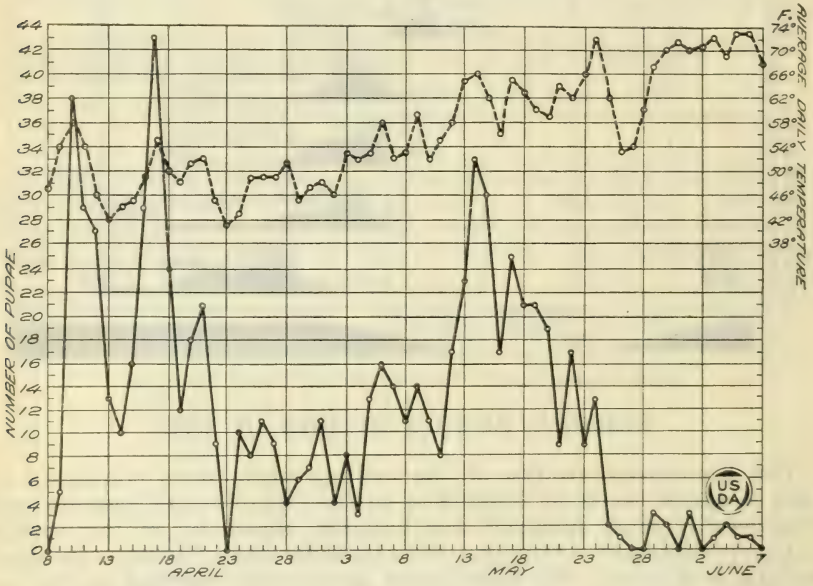


FIG. 23.—Pupation of the spring brood of the codling moth at Yakima, Wash., 1921.

was reached on April 17 and the second maximum on May 14. The first pupa was observed on April 9 and the last on June 6, giving a range of 59 days.

Length of the pupal stage.—Although 229 of the 553 pupæ recorded in Table 33 pupated before April 22, with a minimum average pupal period of 36 days, the extremely high temperatures in the latter part of May and early June so shortened the pupal period of the remaining individuals that the average for all pupæ was 29.53 days. This is the lowest average pupal period for the spring brood that has been recorded in these studies at Yakima.

TABLE 33.—*Length of the pupal stage of pupæ of the spring brood of the codling moth, Yakima, Wash., 1921.*

Date of pupation.	Number of pupæ.	Pupal period in days.			Date of pupation.	Number of pupæ.	Pupal period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
Apr. 10	35	41.46	43	40	May 6	12	24.67	26	22
11	24	41.38	43	40	7	9	23.33	25	17
12	22	41.05	42	40	8	6	23.83	25	23
13	9	39.89	41	38	9	13	23.31	24	22
14	4	39.00	39	39	10	7	22.86	24	22
15	14	39.07	49	38	11	7	22.29	23	22
16	26	38.12	45	37	12	13	21.77	23	21
17	33	37.06	38	36	13	20	20.90	23	20
18	22	36.64	40	35	14	26	21.00	24	20
19	11	36.00	39	35	15	20	20.25	21	19
20	12	36.00	38	34	16	13	19.85	20	19
21	17	36.06	37	33	17	19	19.21	21	18
22	8	35.50	37	32	18	12	19.25	20	18
24	8	33.75	35	31	19	16	18.94	21	18
25	5	33.40	34	33	20	13	18.46	20	18
26	10	32.00	33	29	21	7	18.43	20	17
27	8	31.50	32	31	22	10	18.50	20	16
28	3	31.00	32	30	23	7	18.71	20	17
29	5	31.20	35	29	24	6	19.33	21	18
30	4	28.25	29	28	25	1	19.00	19	19
May 1	9	28.44	29	28	29	2	19.50	20	19
2	3	27.67	28	27	30	1	13.00	13	13
3	3	26.67	27	26	June 1	2	21.00	21	21
4	3	26.00	27	25	4	1	21.00	21	21
5	11	25.18	26	25	5	1	21.00	21	21

Total number of pupæ	553
Average length of pupal stage in days	29.53
Maximum length of pupal stage in days	49
Minimum length of pupal stage in days	13

MOTHS OF THE SPRING BROOD.

Time of emergence.—Figure 24 indicates graphically the time of emergence of 2,165 spring-brood moths, of which 1,896, or 87.5 per cent, emerged between May 22 and June 6, owing to the high temperatures. The result of daily mean temperatures below 55° F. on May 26 and 27 is clearly shown in the accompanying diagram. The first moth emerged May 19, and the last moth on June 27, with a maximum emergence of 259 moths on May 30.

Oviposition by moths of the spring brood.—The high temperatures previously mentioned created nearly ideal conditions for oviposition by spring-brood moths. Consequently the average number of days before oviposition and from emergence to maximum oviposition was 2.47 and 5.53, respectively, which is noticeably less than the same interval in 1919 and 1920. The moths emerging on June 8, which had a maximum of 18 days for each of these periods, were abnormal in that they laid only 4 eggs. Eggs were deposited on the day after emergence in 9 out of 19 instances. The data in Table 34 are for cages rather than individuals.

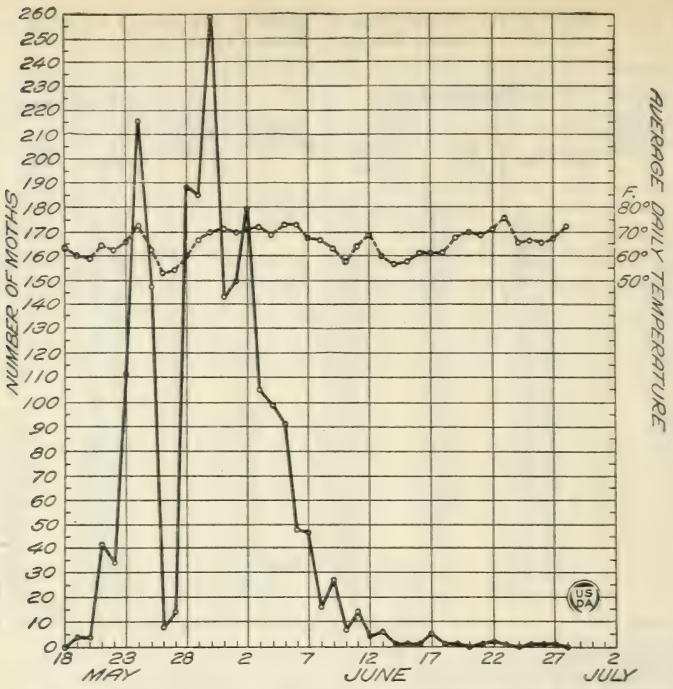


FIG. 24.—Emergence of the spring brood of moths of the codling moth at Yakima, Wash., 1921.

TABLE 34.—*Oviposition by codling moths of the spring brood in rearing cages, Yakima, Wash., 1921.*

Observation.	Number of moths	Sex.		Date of—				Number of days—				Total number of eggs deposited.
		Male.	Female.	Emergence.	First oviposition.	Maximum oviposition.	Last oviposition.	Before oviposition.	From emergence to maximum oviposition.	Of oviposition.	From emergence to last oviposition.	
1	39	33	6	May 21	May 23	May 24	June 8	2	3	17	18	310
2	31	15	16	May 22	May 24	May 25	...do.....	2	3	16	17	726
3	74	45	29	May 23	May 25	May 30	June 13	2	7	20	21	1,042
4	142	66	76	May 24	...do.....	May 31	June 20	1	7	27	27	3,066
5	83	34	49	May 25	May 27	June 4	June 17	2	10	22	23	1,596
6	9	4	5	May 27	May 30	May 30	June 7	3	3	9	11	143
7	110	45	65	May 28	...do.....	June 1	June 12	2	4	14	15	506
8	104	36	68	May 29	...do.....	June 5	June 20	1	7	22	22	508
9	132	44	88	May 30	May 31	June 3	June 22	1	4	23	23	1,251
10	50	26	24	May 31	June 2	June 4	June 19	2	4	18	19	610
11	85	30	55	June 1	...do.....	June 5	June 27	1	4	26	26	1,227
12	91	30	61	June 2	June 3	June 8	June 26	1	6	24	24	794
13	24	9	15	June 3	June 4	June 6	...do.....	1	3	23	23	309
14	61	18	43	June 4	June 5	...do.....	June 22	1	2	18	18	600
15	51	8	43	June 5	June 6	June 11	June 25	1	6	20	20	363
16	21	9	12	June 6	June 7	June 12	June 29	1	6	23	23	428
17	35	12	23	June 7	June 9	...do.....	June 25	2	5	17	18	221
18	10	3	7	June 8	June 26	June 26	July 4	18	18	9	26	4
19	14	3	11	June 9	June 12	June 12	June 26	3	3	15	17	59
Average								2.47	5.53	19.11	20.58	.....
Maximum								18	18	27	27	.....
Minimum								1	2	9	11	.....

Number of male moths	470
Number of female moths	696
Total number of moths	1,166
Total number of eggs	13,763
Average number of eggs per female moth	19.77

Number of eggs per female.—Of the 1,166 moths observed, 696 were females, which deposited 13,763 eggs, or an average of 19.77, which is the highest average for spring-brood moths recorded in Yakima. These data are given in Table 34.

Length of life of moths.—The average length of life of 495 male moths was 12.29 days, of 723 females 13.85 days, or 1.56 days longer than that of the males as shown in Table 35. The length of life of these moths was less by several days than the life of spring-brood moths in either 1919 or 1920.

TABLE 35.—*Length of life of male and female codling moths of the spring brood, Yakima, Wash., 1921.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
2	4	2	0	14	22	14	47	26	2	26	7
3	4	3	2	15	41	15	48	27	3	27	4
4	7	4	4	16	21	16	40	28	2	28	4
5	11	5	10	17	19	17	35	29	2	29	2
6	22	6	28	18	15	18	45	30	2	30	0
7	43	7	47	19	12	19	26	31	0	31	1
8	42	8	42	20	13	20	25	32	0	32	0
9	45	9	43	21	11	21	27	33	1	33	0
10	54	10	50	22	6	22	15	34	0	34	0
11	37	11	52	23	7	23	11	35	0	35	1
12	22	12	49	24	3	24	14				
13	19	13	39	25	3	25	5	Total.	495	Total.	723

Average length of life of male moths, 12.29 days; female moths, 13.85 days.
Maximum length of life of male moths, 33 days; female moths, 35 days.
Minimum length of life of male moths, 2 days; female moths, 2 days.

THE FIRST GENERATION.

EGGS OF THE FIRST BROOD.

Time of egg deposition.—In Figure 25 is given the time of deposition of 14,822 eggs of the first brood. The first eggs were laid on May 23 and the last June 30, covering a period of over five weeks. Mean temperatures above 70° F. for the 6-hour period between 3 and 9 p. m., commencing May 29 and ending June 8, encouraged the moths to deposit 11,390 eggs, or 76.85 per cent of the total number of eggs during these 11 days. The maximum number of eggs laid in a single day was 1,379 on June 4.

Length of incubation.—Embryological studies of 7,999 eggs of the first brood show the average number of days from deposition to the appearance of the red ring to be 3.45; average number of days from deposition to the appearance of the black spot 7.6 days, and the average length of the incubation period 9.31 days. These intervals are shorter than the corresponding intervals recorded for 1919 and 1920. These data are found in Table 36.

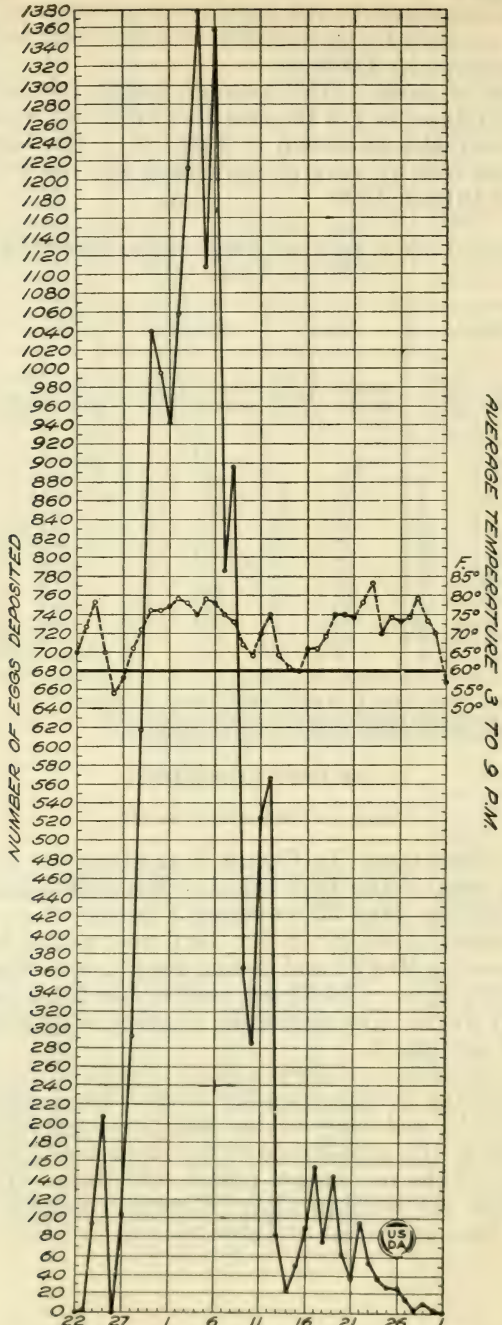


FIG. 25.—Time of deposition of eggs of the first brood of the codling moth at Yakima, Wash., 1921.

TABLE 36.—*Time of deposition and length of incubation of eggs of the first brood of the codling moth, Yakima, Wash., 1921.*

Date of deposition.	Number of eggs.	Number of days from deposition to appearance of—						Incubation period in days.		
		Red ring.			Black spot.			Average.	Maximum.	Minimum.
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.			
May 24	61	4.00	4	4	8.00	8	8	9.03	10	9
25	70	4.00	4	4	8.00	8	8	9.23	10	9
27	60	3.00	3	3	7.00	7	7	8.08	9	8
28	80	3.00	3	3	6.00	6	6	7.19	9	7
29	258	3.00	3	3	6.00	6	6	7.40	8	7
30	497	3.00	3	3	6.00	6	6	7.28	8	7
31	585	3.00	3	3	6.00	6	6	7.27	8	7
June 1	608	3.00	3	3	6.00	6	6	7.02	8	7
2	640	3.00	3	3	6.00	6	6	7.43	8	7
3	690	3.00	3	3	6.00	6	6	8.82	10	8
4	738	3.00	3	3	7.00	7	7	9.52	10	9
5	525	3.00	3	3	7.00	7	7	9.85	10	9
6	462	3.00	3	3	9.00	9	9	10.00	10	10
7	505	4.00	4	4	11.00	11	11	12.20	13	12
8	702	4.00	4	4	10.00	10	10	12.31	13	12
9	228	5.00	5	5	11.00	11	11	12.24	13	12
10	112	5.00	5	5	11.00	11	11	12.29	13	12
11	225	4.00	4	4	10.00	10	10	11.29	12	11
12	292	4.00	4	4	10.00	10	10	11.00	11	11
13	58	7.00	7	7	9.00	9	9	10.45	11	10
14	13	7.00	7	7	9.00	9	9	10.31	11	10
15	43	6.00	6	6	8.00	8	8	9.51	11	9
16	73	6.00	6	6	7.00	7	7	8.64	9	8
17	75	5.00	5	5	7.00	7	7	8.83	9	8
18	73	5.00	5	5	6.00	6	6	8.00	8	8
19	107	4.00	4	4	6.00	6	6	7.98	9	7
20	36	4.00	4	4	7.00	7	7	8.19	9	8
21	28	3.00	3	3	7.00	7	7	8.14	9	8
22	41	3.00	3	3	7.00	7	7	8.00	8	8
23	49	3.00	3	3	7.00	7	7	9.27	10	8
24	12	3.00	3	3	8.00	8	8	9.25	10	9
25	16	3.00	3	3	8.00	8	8	9.31	10	9
26	16	3.00	3	3	8.00	8	8	9.00	9	9
27	14	3.00	3	3	8.00	8	8	9.14	10	9
28	3	5.00	5	5	8.00	8	8	9.00	9	9
29	4	4.00	4	4	8.00	8	8	9.75	11	9
	7,999	3.45	7	3	7.60	11	6	9.31	13	7

LARVÆ OF THE FIRST BROOD.

Time of hatching.—The time of hatching of larvæ of the first brood was quite regular with the exception of June 17 and 18. Mean temperatures below 60° F. on June 14 and 15 so delayed the development of the eggs that no hatching occurred on June 17 and 18. The first larvæ hatched on June 2, and the last on July 10, with a

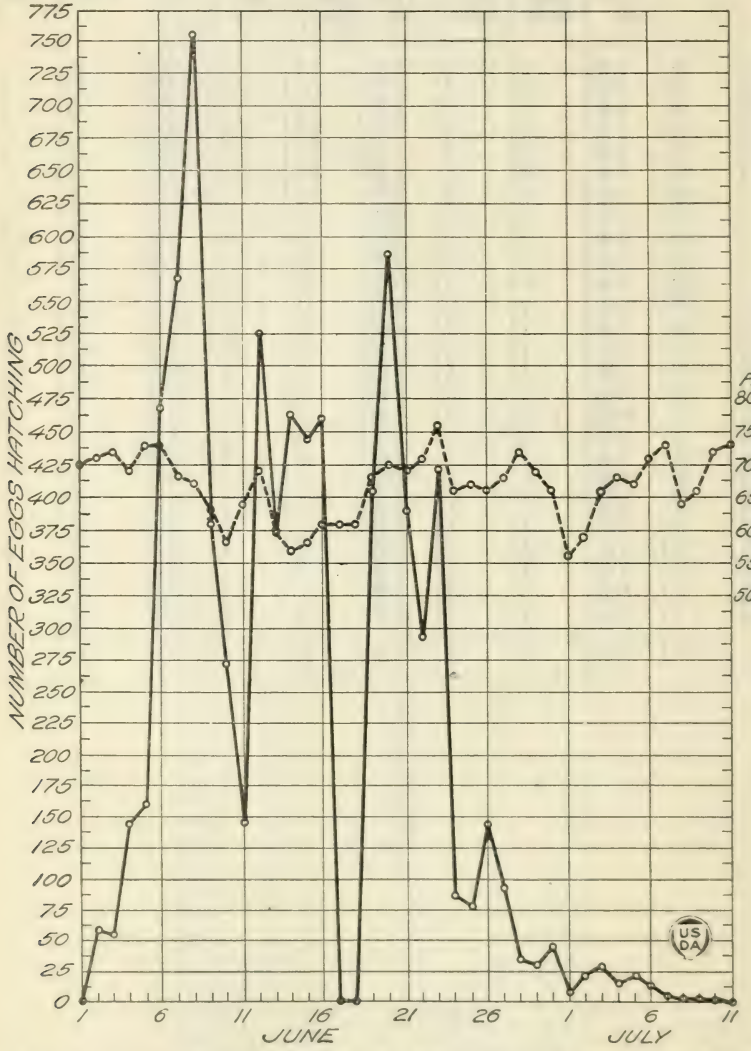


FIG. 26.—Hatching of larvæ of the first brood of the codling moth at Yakima, Wash., 1921.

maximum of 755 on June 8. (See fig. 26.) Larvæ of the first brood were thus hatching over a period of 39 days.

Length of the feeding period.—In Table 37 the length of the feeding period of 722 first-brood larvæ is tabulated. These data include both transforming and nontransforming larvæ.

TABLE 37.—*Length of feeding period of larvæ of the first brood of the codling moth, Yakima, Wash., 1921.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
June 2	2	31.00	34	28	June 22	71	23.99	29	13
3	3	27.33	31	24	23	74	24.54	33	20
4	6	28.67	31	25	24	24	24.54	32	20
5	4	27.75	30	25	25	46	24.48	37	18
8	12	34.33	44	26	26	18	24.78	30	19
9	24	31.38	38	18	27	27	24.89	32	22
10	19	32.53	36	30	28	15	21.80	24	19
11	28	30.25	44	22	29	6	21.33	27	15
12	13	28.77	38	24	30	4	22.50	24	22
13	24	28.08	32	24	July 1	9	22.11	33	13
14	39	26.97	39	19	2	7	22.14	25	20
15	31	30.32	42	25	4	6	22.17	26	19
17	10	27.20	36	22	5	1	18.00	18	18
18	24	27.46	34	24	6	2	21.50	22	21
19	36	25.89	33	21	7	4	21.75	25	20
20	54	24.46	33	20	8	1	17.00	17	17
21	78	23.35	29	12					

Total number of larvæ	722
Average length of feeding period in days	25.83
Maximum length of feeding period in days	44
Minimum length of feeding period in days	12

Length of the cocooning period.—The average number of days which 540 larvæ of the first brood required to build their cocoons was 6.12. The date of leaving the fruit and the average, maximum, and minimum length of the cocooning period of these larvæ are given in Table 38

TABLE 38.—*Length of cocooning period of transforming codling moth larvæ of the first brood, Yakima, Wash., 1921.*

Larvæ left fruit.	Number of larvæ.	Cocooning period in days.			Larvæ left fruit.	Number of larvæ.	Cocooning period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
June 27	2	8.00	8	8	July 15	49	6.37	15	2
29	1	7.00	7	7	16	55	6.76	21	3
30	3	6.00	6	6	17	43	7.40	23	2
July 2	4	6.00	10	4	18	38	5.50	13	4
3	6	8.00	10	5	19	22	6.77	24	2
4	6	5.50	6	5	20	17	5.41	12	3
5	3	6.00	7	5	21	16	4.94	11	1
6	2	5.50	6	5	22	21	5.00	16	2
7	12	5.17	11	4	23	11	6.18	19	2
8	8	5.00	10	4	24	7	8.29	28	4
9	15	4.53	7	4	25	3	9.67	21	3
10	19	5.37	16	3	26	3	4.33	5	4
11	28	6.36	20	3	27	2	3.50	4	3
12	40	5.50	14	4	28	2	14.00	24	4
13	43	6.16	16	3	29	2	15.50	23	8
14	56	5.71	14	3	30	1	6.00	6	6

Total number of larvæ	540
Average length of cocooning period in days	6.12
Maximum length of cocooning period in days	28
Minimum length of cocooning period in days	1

PUPÆ OF THE FIRST BROOD.

Time of pupation.—Pupation by larvæ of the first brood was first observed on July 5 and continued daily, with four exceptions, until August 15. This is shown in Figure 27, which also gives the date of maximum pupation as July 23, when 52 larvæ transformed.

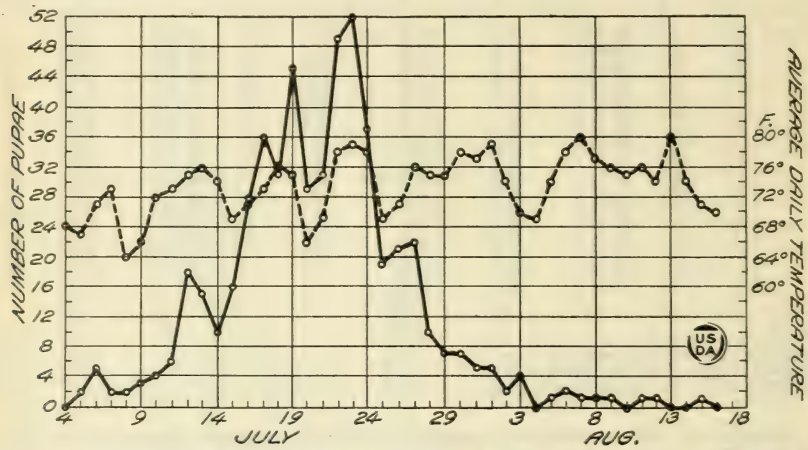


FIG. 27.—Pupation of the first brood of the codling moth at Yakima, Wash., 1921.

Length of pupal stage.—Table 39 shows the length of the pupal stage of 491 pupæ.

TABLE 39.—*Length of the pupal stage of pupæ of the first brood of the codling moth, Yakima, Wash., 1921.*

Date of pupation.	Number of pupæ.	Pupal period in days.			Date of pupation.	Number of pupæ.	Pupal period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 5	2	11.00	11	11	July 24	33	12.36	14	10
6	5	12.80	14	12	25	16	11.88	14	10
7	2	14.50	15	14	26	18	12.89	25	11
8	1	11.00	11	11	27	22	12.32	13	10
9	3	13.00	14	12	28	9	11.89	14	10
10	3	13.00	13	13	29	8	12.50	14	11
11	6	12.67	17	11	30	6	11.67	13	9
12	17	13.18	16	11	31	6	11.83	13	10
13	14	12.14	14	11	Aug. 1	4	12.50	14	12
14	10	12.70	14	12	2	2	11.50	12	11
15	13	12.62	18	11	3	5	12.20	16	10
16	26	13.62	27	10	5	1	11.00	11	11
17	32	13.00	20	11	6	1	14.00	14	14
18	24	12.75	20	9	7	1	13.00	13	13
19	43	12.77	27	6	8	1	17.00	17	17
20	28	12.21	14	11	9	1	12.00	12	12
21	30	12.20	13	11	12	1	16.00	16	16
22	45	11.89	15	6	21	3	23.00	24	22
23	49	12.78	26	10					

Total number of pupæ	491
Average length of pupal stage in days	12.62
Maximum length of pupal stage in days	27
Minimum length of pupal stage in days	6

MOTHS OF THE FIRST BROOD.

Time of emergence.—Moths emerged in the insectary from July 13 to October 9, inclusive, a longer period than heretofore observed. These moths include individuals emerging from material reared in the insectary, and from larvæ collected under bands in the field. Three individuals emerging on September 5, 6, and 7 from insectary-bred material are second-brood moths, and it is assumed that some second-brood moths are included in the moths emerging from field collections. Moths emerged in large numbers for about a month, beginning July 21, with the maximum of 78 on July 31. Figure 28 graphically indicates these data.

Oviposition by moths of the first brood.—The oviposition records of 46 cages in which were confined 645 female moths are given in Table 40. Eggs were laid one day after emergence in 20 of the cages.

Number of eggs per female moth.—Table 40 gives the data on the deposition of 13,154 eggs by 645 females of the first brood, which emerged between July 21 and August 30. This is an average of 20.39 eggs.

TABLE 40.—*Oviposition by codling moths of the first brood in rearing cages, Yakima, Wash., 1921.*

Observation.	Number of moths.	Sex.		Date of—				Number of days—				Total number of eggs deposited.
		Male.	Female.	Emergence.	First oviposition.	Maximum oviposition.	Last oviposition.	Before oviposition.	From emergence to maximum oviposition.	Of oviposition.	From emergence to last oviposition.	
1	20	6	14	July 22	July 23	July 24	Aug. 1	1	2	10	10	211
2	14	9	5	July 23	July 25	July 25	Aug. 3	2	2	10	11	274
3	21	7	14	July 24	...do....	July 27	Aug. 6	1	3	13	13	550
4	32	9	23	July 25	July 26	July 29	Aug. 15	1	4	21	21	330
5	31	12	19	July 26	July 27	July 30	Aug. 8	1	4	13	13	237
6	20	7	13	July 27	July 29	July 29	Aug. 7	2	2	10	11	147
7	38	16	22	July 28	...do....	July 31	Aug. 11	1	3	14	14	646
8	35	12	23	July 29	July 30	July 31	Aug. 12	1	2	14	14	390
9	40	17	23	July 30	July 31	Aug. 1	Aug. 8	1	2	9	9	320
10	79	29	50	July 31	Aug. 1	Aug. 2	Aug. 13	1	2	13	13	1,141
11	55	19	36	Aug. 1	Aug. 2	Aug. 4	Aug. 16	1	3	15	15	992
12	54	13	41	Aug. 2	Aug. 3	Aug. 7	Aug. 15	1	5	13	13	757
13	74	26	48	Aug. 3	Aug. 4	Aug. 6	Aug. 14	1	3	11	11	764
14	20	5	15	Aug. 4	Aug. 6	Aug. 7	Aug. 11	2	3	6	7	356
15	70	22	48	Aug. 5	...do....	...do....	Aug. 20	1	2	15	15	1,666
16	63	23	40	Aug. 6	Aug. 8	Aug. 8	Aug. 23	2	2	16	17	715
17	35	13	22	Aug. 7	...do....	Aug. 10	Aug. 19	1	3	12	12	421
18	40	11	29	Aug. 8	Aug. 9	Aug. 13	Aug. 26	1	5	18	18	307
19	36	12	24	Aug. 9	Aug. 12	Aug. 14	...do....	3	5	15	17	507
20	18	9	9	Aug. 10	...do....	Aug. 19	Aug. 23	2	9	12	13	59
21	26	9	17	Aug. 11	...do....	Aug. 15	Aug. 27	1	4	16	16	269
22	18	5	13	Aug. 12	Aug. 14	Aug. 14	Aug. 23	2	2	10	11	186
23	30	9	21	Aug. 13	...do....	Aug. 15	Sept. 1	1	2	19	19	234
24	9	4	5	Aug. 14	Aug. 15	...do....	Sept. 2	1	1	19	19	114
25	24	10	14	Aug. 15	Aug. 18	Aug. 23	...do....	3	8	16	18	232
26	15	5	10	Aug. 16	...do....	Aug. 22	Aug. 30	2	6	13	14	135
27	5	2	3	Aug. 17	Aug. 20	...do....	Aug. 27	3	5	8	10	65
28	13	5	8	Aug. 18	Aug. 19	Aug. 20	Aug. 31	1	2	13	13	95
29	16	9	7	Aug. 19	Aug. 20	Aug. 25	Sept. 7	1	6	19	19	414
30	15	4	11	Aug. 20	Aug. 23	Aug. 24	Sept. 5	3	4	14	16	99
31	15	9	6	Aug. 21	Aug. 25	Aug. 30	Sept. 9	4	9	16	19	296
32	5	4	1	Aug. 22	Aug. 29	Aug. 29	Aug. 29	7	7	1	7	2
33	8	5	3	Aug. 28	...do....	Aug. 30	Sept. 26	1	2	29	29	104
34	10	2	8	Aug. 29	Aug. 31	Sept. 3	Sept. 7	2	5	8	9	119
Average								1.74	3.79	13.56	14.29	.....
Maximum								7	9	29	29	.....
Minimum								1	2	1	7	.....

Number of male moths	359
Number of female moths	645
Total number of moths	1,004
Total number of eggs	13,154
Average number of eggs per female moth	20.39

Length of life of moths.—Table 41 shows that the average length of life of 356 male moths of the first brood was 11.72 days; of 643 females, 11.39 days.

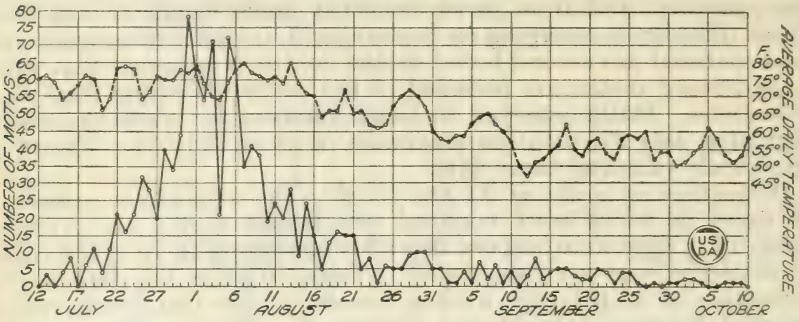


FIG. 28.—Emergence of the first and second broods of moths of the codling moth at Yakima, Wash., 1921.

TABLE 41.—*Length of life of male and female codling moths of the first brood, Yakima, Wash., 1921.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
1	3	1	3	14	19	14	35	26	1	26	2
2	1	2	1	15	17	15	23	27	1	27	1
3	4	3	10	16	16	16	28	28	2	28	1
4	18	4	22	17	9	17	31	29	1	29	0
5	14	5	21	18	5	18	12	30	1	30	0
6	21	6	44	19	11	19	20	34	1	34	1
7	36	7	65	20	5	20	8	35	1	35	0
8	20	8	37	21	12	21	6	37	1	37	0
9	24	9	49	22	4	22	6	39	1	39	0
10	33	10	68	23	2	23	4	50	0	50	1
11	29	11	46	24	2	24	3				
12	21	12	44	25	2	25	7	Total..	356	Total.	643
13	18	13	44								

Average length of life of male moths, 11.72 days; female moths, 11.39 days.
Maximum length of life of male moths, 39 days; female moths, 50 days.
Minimum length of life of male moths, 1 day; female moths, 1 day.

LIFE CYCLE OF THE FIRST GENERATION.

Table 42 shows the periods in the life of 490 individuals of the first generation from the time of deposition of the egg to the emergence of the adult. From this table the average life cycle is found to be 54.14 days, to which must be added 1.74 days, the average length of the preoviposition period, to give the complete life cycle from egg to egg, which in this case is 55.88 days. All larvæ were brought through the feeding period by the stock-jar method.

TABLE 42.—*Life cycle of the first generation of the codling moth as observed by rearing, stock-jar feeding method, Yakima, Wash., 1921.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.[1]		
			Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
			Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
May 24	2	9	31.00	34	28	5.50	6	5	12.50	13	12	58.00	60	56
25	3	9	27.33	31	24	6.67	8	6	12.33	13	11	55.33	59	52
27	5	8	28.20	30	25	5.40	7	5	13.40	15	12	55.00	57	52
29	3	7	27.00	28	25	5.00	6	4	13.00	14	12	52.00	54	50
June 1	8	7	32.13	38	26	6.25	11	3	12.38	13	11	57.76	64	52
2	17	7	30.18	38	18	7.88	16	3	12.53	16	11	57.59	60	44
2	11	8	32.36	36	30	7.45	16	4	12.73	14	10	60.54	69	54
3	18	8	28.83	34	22	5.44	9	4	13.17	18	12	55.44	60	51
3	9	9	28.00	30	24	4.78	6	4	14.00	27	11	55.78	70	50
4	15	9	27.27	32	24	4.93	8	3	12.33	16	9	53.53	61	50
4	30	10	26.23	30	19	5.10	16	3	12.63	17	11	53.97	68	45
5	11	10	29.18	39	25	9.18	28	3	13.45	23	10	61.82	100	51
6	4	11	24.75	31	22	4.75	6	4	13.50	14	13	54.00	61	50
6	12	12	26.33	30	24	7.08	12	4	13.42	18	11	58.83	64	52
7	30	12	25.67	31	21	6.07	18	2	12.53	20	10	56.27	72	49
8	34	12	24.47	33	20	6.91	18	3	12.26	14	10	55.65	68	46
9	59	12	23.90	29	19	6.05	23	2	12.90	20	10	54.85	73	45
10	60	12	23.80	29	13	6.58	24	3	12.72	25	10	55.10	79	42
12	51	11	24.35	31	20	5.82	14	4	12.69	26	10	53.86	61	47
15	15	9	23.73	32	20	5.60	17	3	12.20	14	11	50.53	61	46
16	33	9	23.61	29	18	5.61	20	3	12.61	27	10	50.82	70	42
18	10	8	23.70	29	19	5.70	16	1	11.60	13	10	49.00	63	43
19	18	8	24.56	32	22	5.39	11	3	12.00	14	10	49.95	62	45
20	7	8	20.71	22	19	4.29	5	4	11.29	13	10	44.29	47	42
21	5	8	20.60	27	15	4.20	6	3	10.60	12	6	43.40	51	34
22	4	8	22.50	24	22	4.00	4	4	11.00	11	11	45.50	47	45
23	6	8	20.33	28	13	6.83	23	2	12.50	22	7	47.66	81	33
23	4	9	22.25	25	21	4.25	5	3	11.75	14	11	47.25	49	46
25	1	9	26.00	26	26	6.00	6	6	11.00	11	11	52.00	52	52
26	1	9	18.00	18	18	4.00	4	4	12.00	12	12	43.00	43	43
27	2	9	21.50	22	21	14.00	24	4	18.00	24	12	62.50	79	46
28	1	9	21.00	21	21	4.00	4	4	12.00	12	12	46.00	46	46
29	1	9	17.00	17	17	5.00	5	5	9.00	9	9	40.00	40	40
	490	10.22	25.23	39	13	6.07	28	1	12.62	27	6	54.14	100	33

[1] Add 1.74 days for complete life cycle.

THE SECOND GENERATION.

EGGS OF THE SECOND BROOD.

Time of deposition.—The complete period over which the first brood of moths laid eggs extended over the 91 days beginning July 15 and ending October 13, although 12,021 eggs, or 77 per cent of the total number, were deposited during the four weeks beginning

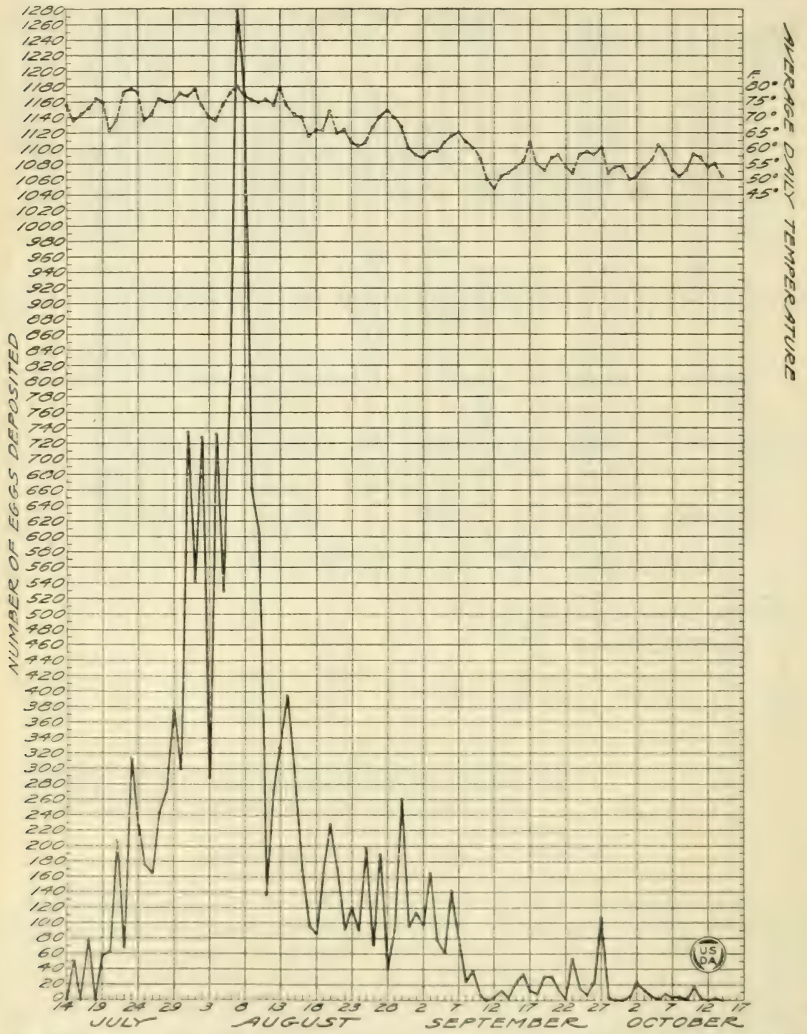


FIG. 29.—Time of deposition of eggs of the second brood of the codling moth at Yakima, Wash., 1921.

July 21 and ending August 16. The greatest number of eggs deposited in one day was 1,278 on August 7, one of the two dates on which the highest average daily temperature of the year was recorded. Figure 29 gives the time of deposition of 15,527 eggs of the second brood.

Length of incubation.—The length of the incubation period of 5,342 eggs of the second brood, the number of days from deposition to the appearance of the red ring, and the number of days from deposition to the appearance of the black spot are given in Table 43. The incubation period of eggs which were deposited after August 30 was about three times as long as required by eggs which hatched in July and early August. This is due to daily average temperatures generally below 60° F.

TABLE 43.—*Time of deposition and length of incubation of eggs of the second brood of the codling moth, Yakima, Wash., 1921.*

Date of deposition.	Number of eggs.	Number of days from deposition to appearance of—						Incubation period in days.		
		Red ring.			Black spot.			Average.	Maximum.	Minimum.
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.			
July 15	31	3.00	3	3	6.00	6	6	7.03	8	7
17	6	2.00	2	2	6.00	6	6	7.17	8	7
18	23	3.00	3	3	6.00	6	6	7.09	8	7
20	4	3.00	3	3	5.00	5	5	6.50	7	6
21	19	3.00	3	3	5.00	5	5	6.16	7	6
22	11	3.00	3	3	6.00	6	6	7.00	7	7
23	124	3.00	3	3	5.00	5	5	6.77	7	6
24	132	3.00	3	3	6.00	6	6	6.92	7	6
25	64	3.00	3	3	5.00	5	5	6.34	7	6
26	41	3.00	3	3	5.00	5	5	6.46	7	6
27	45	3.00	3	3	5.00	5	5	6.22	7	6
28	93	3.00	3	3	5.00	5	5	6.10	7	6
29	120	3.00	3	3	5.00	5	5	6.17	7	6
30	242	3.00	3	3	5.00	5	5	6.98	7	6
31	352	2.00	2	2	6.00	6	6	7.00	7	7
Aug. 1	183	2.00	2	2	5.00	5	5	6.52	7	6
2	210	2.00	2	2	6.00	6	6	7.00	7	7
3	19	2.00	2	2	5.00	5	5	6.00	6	6
4	198	2.00	2	2	5.00	5	5	6.00	6	6
5	200	2.00	2	2	5.00	5	5	6.33	7	6
6	456	2.00	2	2	5.00	5	5	6.00	6	6
7	511	3.00	3	3	5.00	5	5	6.32	8	6
8	470	2.00	2	2	5.00	5	5	6.00	6	6
9	243	2.00	2	2	5.00	5	5	6.28	7	5
10	144	2.00	2	2	5.19	6	5	6.19	7	6
11	180	2.00	2	2	6.00	6	6	7.58	8	7
12	60	2.00	2	2	6.00	6	6	8.00	8	8
13	61	2.00	2	2	7.00	7	7	8.00	8	8
14	192	3.00	3	3	7.00	7	7	9.09	10	8
15	53	3.00	3	3	7.00	7	7	9.21	10	8
16	60	3.00	3	3	8.38	9	8	10.42	12	9
17	24	3.00	3	3	8.00	8	8	10.29	11	10
18	37	3.00	3	3	8.00	8	8	9.24	10	9
19	38	3.00	3	3	8.00	8	8	9.42	10	9
20	69	3.00	3	3	8.00	8	8	9.64	10	9
21	55	3.00	3	3	8.00	8	8	9.58	10	9
22	52	3.00	3	3	8.00	8	8	9.33	11	9
23	54	3.00	3	3	8.00	8	8	10.07	11	9
24	42	3.00	3	3	8.00	8	8	10.43	11	10
25	20	3.00	3	3	8.00	8	8	11.25	13	10
26	3	4.00	4	4	9.00	9	9	11.00	11	11
27	53	4.00	4	4	9.00	9	9	11.30	12	11
29	18	4.00	4	4	10.00	10	10	16.11	17	15
30	71	4.00	4	4	14.00	14	14	17.41	18	16
31	15	6.00	6	6	15.00	15	15	17.67	19	17
Sept. 1	45	6.00	6	6	14.13	15	14	17.13	18	17
2	26	6.00	6	6	15.00	15	15	17.35	18	17
3	44	5.00	5	5	15.00	15	15	17.66	19	16
4	34	4.00	4	4	14.00	14	14	17.35	19	17
5	18	6.00	6	6	15.00	15	15	18.44	19	17
6	35	6.00	6	6	15.00	15	15	19.00	20	18
7	20	6.00	6	6	17.00	17	17	19.95	21	18
8	12	7.00	7	7	18.00	18	18	21.83	23	20
9	7	8.00	8	8	18.00	18	18	21.43	23	20
10	3	9.00	9	9	18.00	18	18	21.00	21	21
	5,342	2.64	9	2	6.23	18	5	7.70	23	5

LARVÆ OF THE SECOND BROOD.

Time of hatching.—The first larvæ of the second brood were recorded on July 22, and worms continued to hatch until October 2. The maximum number of larvæ hatching in one day was 954 on August 12, or 21 days after the earliest larvæ appeared. No worms were hatched from eggs deposited later than September 13. The time of hatching of second-brood eggs is found in Figure 30.

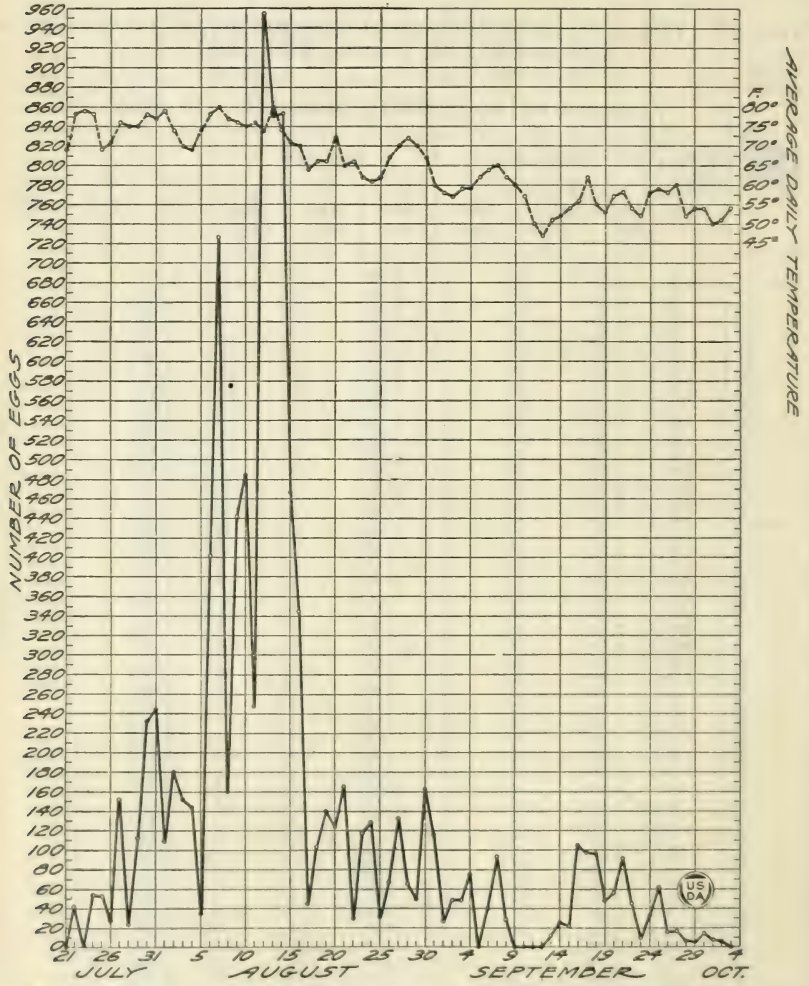


FIG. 30.—Hatching of larvæ of the second brood of the codling moth at Yakima, Wash., 1921.

Length of feeding period of wintering larvæ.—The average length of the feeding period by the stock-jar method of 559 nontransforming larvæ of the second brood was 34.02 days. The details of this period and the effect of lower temperatures from August 14 to September 19 in lengthening the feeding period are shown in Table 44.

TABLE 44.—*Length of feeding period of wintering larvæ of the second brood of the codling moth, Yakima, Wash., 1921.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 22	7	24.14	29	19	Aug. 15	30	42.96	56	29
23	1	20.00	20	20	16	14	39.93	58	31
25	5	21.40	22	20	17	11	43.00	55	28
26	1	20.00	20	20	18	12	44.58	51	34
27	6	25.50	40	21	19	6	38.17	54	17
28	3	17.67	18	17	20	9	42.11	47	33
29	11	20.64	28	18	21	7	47.00	52	42
30	20	26.65	41	20	22	15	48.80	65	39
31	14	23.71	26	20	23	6	42.83	48	38
Aug. 1	19	22.68	29	17	24	8	48.75	71	42
2	13	25.08	31	20	25	2	54.50	62	47
3	18	27.72	40	21	26	3	56.33	64	46
4	38	26.37	48	19	27	10	48.00	61	43
5	25	28.80	49	19	30	3	47.00	59	39
6	30	27.97	44	21	31	4	52.75	58	43
7	28	28.25	44	19	Sept. 1	3	63.00	72	55
8	14	27.43	36	19	2	4	63.50	70	56
9	24	27.13	40	19	3	3	60.33	71	50
10	27	30.96	54	12	4	4	63.00	66	60
11	18	32.83	49	23	6	1	61.00	61	61
12	32	35.34	48	26	7	3	58.67	61	54
13	26	36.62	60	14	15	1	56.00	56	56
14	19	39.89	61	28	19	1	39.00	39	39

Total number of larvæ	559
Average length of feeding period in days	34.02
Maximum length of feeding period in days	72
Minimum length of feeding period in days	12

Transforming larvæ of the second brood.—Five transforming second-brood larvæ which left the fruit between August 10 and August 25 had an average feeding period of 16.6 days. The average length of the cocooning period of four of these larvæ was 2.5 days. From the resulting pupæ, three female moths emerged, after passing through an average pupal period of 17.67 days. The length of the life cycle of the second brood was not computed, owing to the small number of transforming larvæ. These moths deposited 43 infertile eggs.

CODLING-MOTH BAND STUDIES OF 1921.

Band-record studies were continued in the Guthrie orchard at Yakima in 1921. Twelve of the larger trees were scraped and banded, and 3,666 larvæ were collected during the season. The first larvæ were found under bands on June 22. The last collection was made on October 14, after the fruit was harvested. Although there is some overlapping of broods in the band collections, the insectary studies indicate that August 9 may be considered the arbitrary division point between the first and second broods of larvæ. Accordingly, the maximum collection for the first brood was 149 larvæ on July 22, and for the second brood 179 larvæ on August 30.

The results of these studies are given in Figure 31.

No band-record studies were made in the Walden orchard in 1921.

A summary of the seasonal history of the codling moth for 1921 is shown in Figure 32.

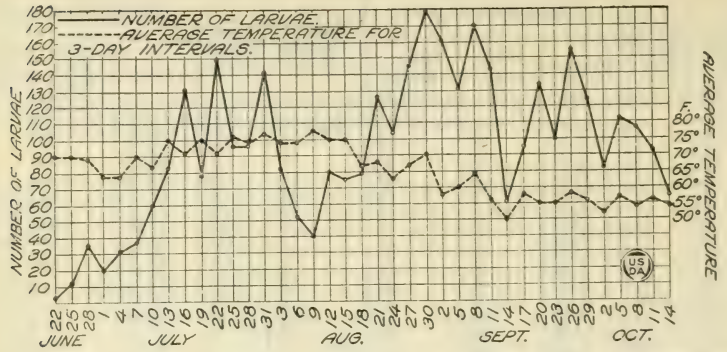


FIG. 31.—Occurrence of codling moth larvæ under bands on apple trees at Yakima, Wash., 1921.

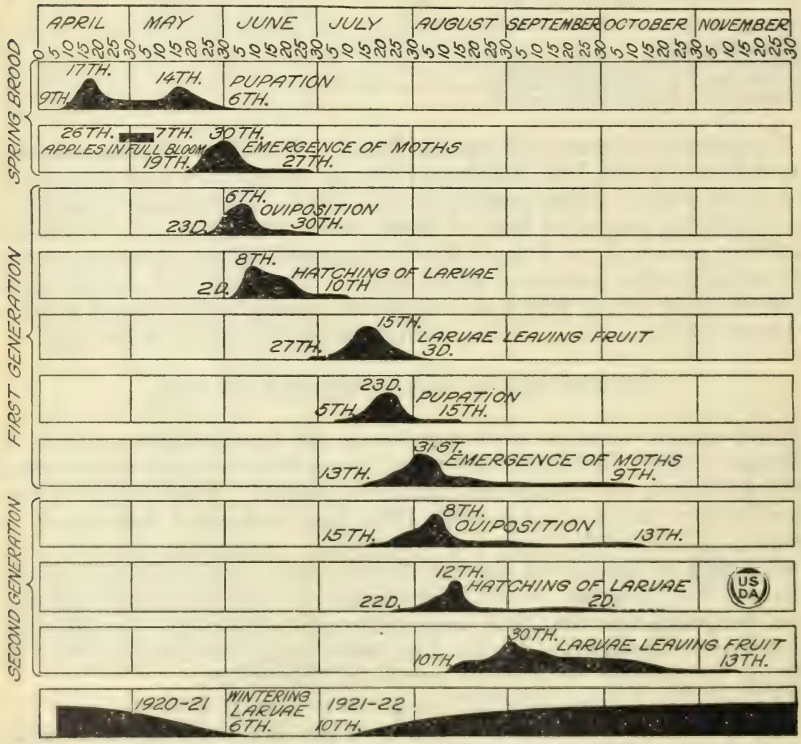


FIG. 32.—Seasonal history of the codling moth at Yakima, Wash., 1921.

VARIATIONS IN THE SEASONAL HISTORY OF THE CODLING MOTH IN THE UPPER AND LOWER YAKIMA VALLEYS.

Owing to the fact that the Yakima Valley is divided into two large sections, the upper and the lower valleys, and that the season in the lower valley is somewhat earlier than in the upper, some studies were made by means of banded trees and screen cages to ascertain the effect this difference would have on the seasonal history of the codling moth.

In Figure 33 a comparison is made between band records secured in 1919 at Yakima in the upper valley, and at Buena in the lower valley (see also p. 20). The solid line is a record of the occurrence of larvæ under bands at Yakima, with an elevation of 1,100 feet, and the dotted line records the same thing for Buena, with an elevation of 850 feet, the two stations being approximately 16 miles apart. At Buena the maximum number of first-brood larvæ occurred July 3, and at Yakima a high point was reached July 17, which, judging from insectary records, probably represents the true maximum more accurately than the high point of August 1. Thus there was an interval

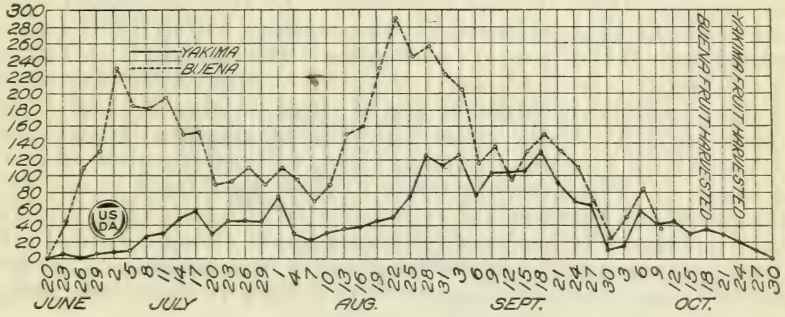


FIG. 33.—Occurrence of codling moth larvæ under bands on apple trees at two points in the Yakima Valley, Wash., 1919.

of 14 days between the two stations. For the second brood the maximum at Buena occurred August 23. At Yakima the actual maximum occurred September 18, 26 days later, but this was due to an accumulation of larvæ delayed by cold weather occurring September 8 to 13, and it is believed that the true maximum should have been about September 3, or 11 days later than at Buena.

In 1920 not enough larvæ were secured at Buena to show conclusively when the maximum for the broods occurred, but the apparent maximum at Buena occurred several days before that at Yakima.

Temperature records were kept in the orchard at Buena in 1920 and 1921 with a thermograph, and a comparison of these with similar orchard records at Yakima shows that the average monthly temperature at Buena is higher than that at Yakima. The average difference in 1920 and 1921 for each month during which records were taken has been figured and was as follows: April, 4.7°; May, 3°; June, 3.1°; July, 2.4°; August, 2.3°; September, 2.4°; the average for the season being 3°.

Screen cages containing from 50 to 200 larvæ were also placed at various points in both valleys in 1920, 1921, and 1922 and examined

every three days during the time the spring brood of moths were emerging. These cages were stocked with larvæ in the fall, the larvæ being allowed to spin cocoons under a burlap band around a section of a tree limb held upright in the center of the cage. The cages were placed in the crotches of trees in orchards early in March, before any development had taken place. They were thus kept under as nearly normal conditions as possible. The elevation at these stations ranged from 800 to 2,000 feet. These cages differed very little in the time of emergence of moths. At most of the stations the maximum emergence occurred within three days of the maximum date at the insectary at Yakima. Thus in 1920 the maximum date at Yakima was June 2. Of 13 cages, the maximum emergence occurred in 10 of them during the period from June 1 to June 4, inclusive. Of the other three cages, one was in the lower valley on a south slope, and the maximum occurred May 21, and the other two were at elevations 600 and 1,000 feet higher than Yakima, and the maximum emergence occurred on June 8 and June 15, respectively. In 1921 the maximum emergence at the insectary and in a cage in the experimental orchard occurred on May 30. In the other nine cages it occurred from three to nine days later. In 1922 maximum emergence of moths again occurred at most stations within a few days of the maximum at the insectary at Yakima. The maximum at Yakima was on June 1. In the lower valley two stations were maintained and the maximum occurred at one of them on May 27, and at the other on May 30. In the upper valley the maximum at two stations was May 30; at five, June 2; and at one, with an elevation of 2,000 feet, June 8. This evidence tends to show that there is not very much difference between different parts of the two valleys in the time of emergence of moths of the spring brood, though, owing to the warmer summer weather in the lower valley, the majority of the first brood of larvæ became full-grown from a week to two weeks earlier than in the upper valley.

SEASONAL-HISTORY STUDIES AT WENATCHEE, WASH., 1915 AND 1916.

During the seasons of 1915 and 1916 the senior author, while stationed in the Wenatchee Valley of Washington, undertook some life-history studies of the codling moth. Since these were carried on as a minor project, it was not possible to make as detailed studies as have been made at Yakima, but it is deemed advisable to present here a summary of the data that were obtained in order that a comparison may be drawn between the two districts.

The Wenatchee Valley is situated in central Washington, about 60 miles north of Yakima. The elevation at Wenatchee, which is just south of the confluence of the Wenatchee and Columbia Rivers, is only about 800 feet, but as the valley is nearer the Cascade Mountains than the Yakima Valley the season is about the same. The average apple crop in the Wenatchee district is about the same as that of the Yakima district.

The winter of 1914–15 was mild and the spring early. Maximum temperatures of 80° F. or more were experienced on April 16 to 19, inclusive, which is unusual for this month. Warm weather was again experienced during the first week in May, after which temperatures

were somewhat below normal, and the precipitation was relatively heavy. The early part of June was cool, but the rest of the summer was unusually warm. Of the 72 days in the period from June 21 to August 31, inclusive, 38 days had maximum temperatures of 90° F. or over. The apple trees were in full bloom April 15 to 20.

Figure 34 gives a summary of the stages in the life history of the codling moth that were chiefly studied in 1915. The maximum pupation occurred during the warm weather in April and the maximum emergence of spring-brood moths just one month later. Of 144 pupæ observed, the average pupal period was 30.44 days.

No further studies of the codling moth were made until late in June. Newly hatched larvæ had been first noted entering the fruit on trees in the laboratory yard on May 29, and on June 27 the mature larvæ were beginning to leave the fruit. On this date 226 wormy apples were collected to secure material for further observations.

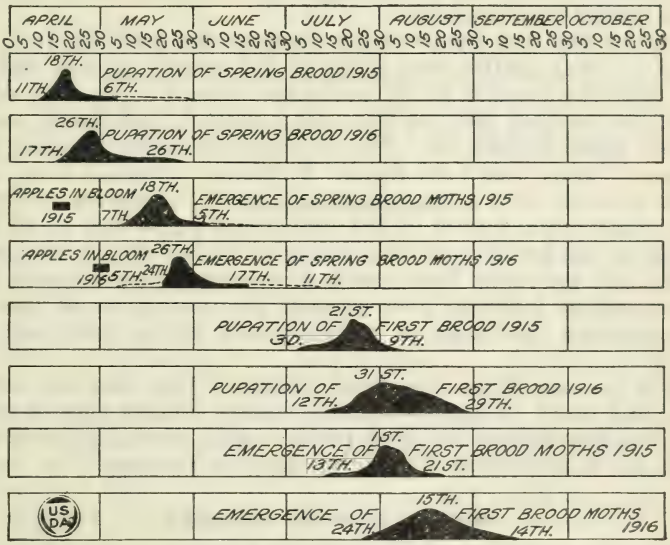


FIG. 34.—Partial seasonal history of the codling moth at Wenatchee, Wash., 1915 and 1916.

Of the 179 first-brood larvæ observed, the average cocooning period was 6.82 days. Pupation began July 3, as shown in Figure 34, and continued until August 9, with a maximum on July 21. The average pupal period of these first-brood individuals was 11.87 days. Moths began emerging from them on July 13 and continued until August 21, with a maximum on August 1.

Larvæ of the second generation began leaving the fruit on August 24, reached a maximum on September 4, and continued to leave the fruit until October 6. No evidence of a third generation was obtained.

In 1916, the season was later than in 1915, but little warm weather being experienced until the second week in June, when it suddenly became hot, temperatures going above 90° F. on June 13 to 17 inclusive, and above 100° F. on the last two days of this period. This hot weather was followed by two weeks of abnormally cool,

rainy weather. Thereafter the weather was not unusually warm until the last week in August, when temperatures of 100° F. or more were again experienced for five or six days. With a cooler spring, the development of trees was delayed, and apples were not in full bloom until about the beginning of May, nearly two weeks later than in 1915.

Figure 34 summarizes the data secured on several of the stages of the codling moth in 1916. Pupation was at a maximum on April 26, and the average length of the pupal stage was 31.29 days. Moths of the spring brood began emerging in the orchards early in May, though none was secured at the insectary from the limited material available until May 20. There was a maximum emergence on May 24, and emergence continued until June 17, though, owing to the cool weather of the latter part of June, a few moths emerged in the orchards as late as July 11. Only general observations were made on oviposition, and this work began late in May and continued as long as moths were present.

Larvæ of the first brood began leaving the fruit on July 5. On July 11 an examination was made of 687 wormy apples, and it was found that the mature larvæ had gone from 5.6 per cent of these. The largest number left the fruit on August 3, and larvæ continued to leave until August 24. The average cocooning period for 493 first-brood larvæ was 6.42 days. Pupation occurred from July 12 until August 29, with a maximum on July 31, as shown in Figure 34. The average pupal period of 493 first-brood pupæ was 13.49 days.

Moths of the first brood were emerging from July 24 until September 14, and probably later, with a maximum on August 15, and the oviposition followed very closely the emergence of the moths. The maximum hatching of second-brood larvæ occurred August 15 to 20.

It will be seen from this brief summary that the life history of the codling moth in the Wenatchee Valley follows very closely that in the Yakima Valley, but each period would probably occur slightly later in the same year at Wenatchee than at Yakima.

MISCELLANEOUS STUDIES.

WINTERKILLING OF LARVÆ.

It is a common occurrence to find winterkilled codling moth larvæ when examining trees in the spring. Some larvæ appear to succumb to fewer degrees of cold than others, but, as the cold increases, increasing numbers of larvæ are killed. An opportunity of studying this effect of the cold was afforded in the winter of 1919–1920. In December, 1919, minimum temperatures were experienced in the Yakima Valley lower than any previously recorded. On December 9 and 10, a severe snowstorm occurred, with some wind. The storm cleared away on the 11th, and minimum temperatures of zero or lower were recorded for the four succeeding days. On December 13 the Weather Bureau observer at Yakima reported −24° F. while the minimum thermometer at the insectary recorded −25.5° F. Unofficial reports from various points in the Yakima Valley showed minimum temperatures of −15° to −30° F. During this cold period there were from 4 to 18 inches of snow on the ground.

After December 15, the weather gradually became warmer, and for a number of days the temperature remained above the freezing point.

All the wintering larvæ in the insectary succumbed to this extreme cold. Examinations of larvæ wintering on apple trees were made in various localities during the succeeding two months in order to ascertain the effect of different degrees of freezing on the larvæ. It was found that where minimum temperatures of $-15°$ to $-20°$ F. had been experienced from 70 to 80 per cent of the larvæ were killed. Minimum temperatures of $-20°$ to $-25°$ F. had killed from 80 to 90 per cent of the larvæ, and minimum temperatures of $-25°$ F. and lower had killed all the larvæ. In all cases the larvæ examined had no other protection than bark or burlap bands. Larvæ occurring below the snow line of December 13 or in the soil all survived, no frozen individuals being found in these places. These protected individuals made possible the continuance of the codling moth in the colder localities.

On January 18 and 19, 1922, the minimum temperature at Yakima was $-4°$ and $-8°$ F., respectively, and on several other days in January the minimum was zero. An examination of wintering larvæ on the trunks of apple trees near Yakima was made April 17. Of 346 larvæ examined, 15, or 4.3 per cent, had been frozen.

WINTERING PERIOD.

During the season of 1920, records were kept of the date of leaving fruit of all wintering larvæ, and in the spring of 1921 the dates of pupation of these larvæ were recorded. These figures show a wide variation in the length of this period. One lot of 176 larvæ collected under bands on September 18, 1920, which had all probably left the fruit within a period of three or four days, pupated over a period of 58 days in the spring of 1921, or from April 10 to June 6, inclusive, as shown in Table 45. The pupal period was more than usually prolonged in 1921, however, owing to fluctuations of temperature. A cold wave in the middle of the pupation period, from April 21 to May 4, delayed the pupation of many larvæ and resulted in two maximum periods of pupation instead of the usual one (see Fig. 23). On the other hand, there is a definite tendency of the earlier-maturing larvæ to pupate earlier than those maturing later in the fall. The pupation of 49 wintering first-brood larvæ was recorded, and of these 35, or 71 per cent, pupated during the first half of the pupation period, that is, April 9 to May 5, inclusive. Records were obtained of 499 wintering individuals of the second brood, exclusive of the lot of 176 mentioned above. As shown in Table 46, approximately half of the larvæ leaving the fruit in August pupated before May 5. Of those maturing in September, about two-thirds pupated before May 5, while of those maturing in October, only one-third pupated before May 5.

TABLE 45.—*Wintering period of codling moth larvæ of the second brood collected under bands at Yakima, Wash., September 18, 1920.*

Date of pupation	Wintering period in days	Number of individuals	Date of pupation	Wintering period in days	Number of individuals	Date of pupation	Wintering period in days	Number of individuals
1921			1921			1921		
Apr. 10	204	4	Apr. 27	221	1	May 15	239	12
11	205	5	May 1	225	1	16	240	6
12	206	3	2	226	1	17	241	4
14	208	1	4	228	1	18	242	4
15	209	2	5	229	3	19	243	5
16	210	5	6	230	6	20	244	5
17	211	8	7	231	4	21	245	2
18	212	8	8	232	5	22	246	7
19	213	3	9	233	7	23	247	4
20	214	2	10	234	5	24	248	3
21	215	7	11	235	5	29	253	1
22	216	3	12	236	8	June 4	259	2
25	219	3	13	237	5	6	261	1
26	220	2	14	238	12			
								176

Average number of days in wintering period..... 229.79
Maximum number of days in wintering period..... 261
Minimum number of days in wintering period..... 204

TABLE 46.—*Time of pupation of wintering larvæ of the second brood of the codling moth, Yakima, Wash., 1921.*

Date of leaving fruit.	Number of individuals.	Date of pupation.			
		April 9 to May 5, 1921.		May 6 to June 5, 1921.	
		Number.	Per cent.	Number.	Per cent.
Aug. 22–31	39	18	46	21	54
Sept. 1–15	201	135	67	66	33
Sept. 16–30	140	92	66	48	34
Oct. 1–15	75	26	35	49	65
Oct. 16–30	44	14	32	30	68
Total	499	285	57	214	43

EMERGENCE OF MOTHS FROM THE SOIL.

In the Yakima Valley a considerable number of wintering codling-moth larvæ spin their cocoons in the soil about the bases of the trees. Most of these cocoons are found in the first inch or two of soil and immediately adjacent to the trunk of the tree. (Pl. III, fig. 2.) Examinations of trash and soil away from the trunk of the tree have failed to show any appreciable number of cocoons. In the fall of 1921, five unsprayed trees were carefully examined, and 2,780 wintering larvæ were collected. Of these, 578, or 21 per cent, were in the soil.

On account of the large number of worms cocooning in the soil, it was thought desirable to ascertain what effect this fact has on the emergence of the spring brood of moths. Accordingly, in the fall of 1919, four screen cages were arranged, two of which each had an upright stump with a burlap band around it secured to the floor to simulate a banded orchard tree. The other two were each equipped with an upright piece of wood in the same position as the stump,

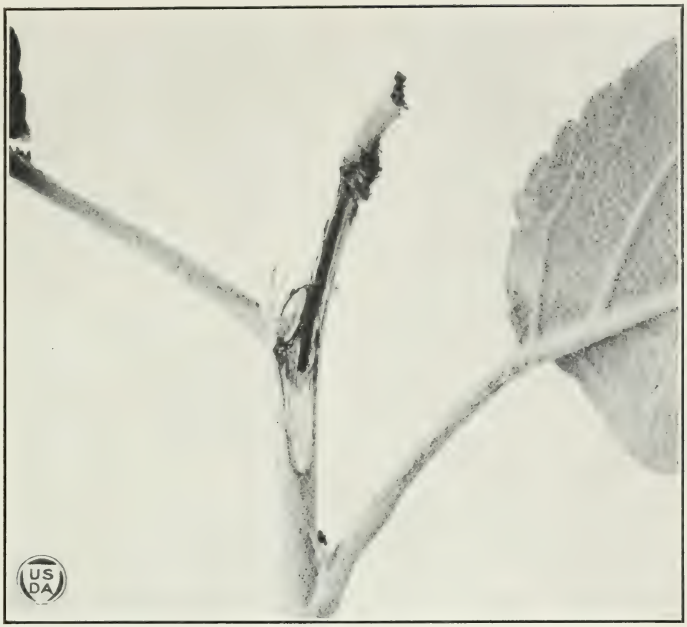


FIG. 1.—TERMINAL SHOOT OF APPLE EXCAVATED BY LARVA

FIG. 2.—PUPAL SHELLS PROTRUDING FROM SOIL AT BASE OF APPLE TREE

THE CODLING MOTH IN THE YAKIMA VALLEY OF WASHINGTON

and several inches of soil was placed in them, about the pieces of wood, which latter were too smooth to afford a cocooning place for the worms above the soil surface (Pl. II, fig. 2). Each cage was stocked with 160 worms in September, 1919, but the extreme cold in December froze those in the band cages and some in the soil cages. Consequently, in February, 1920, 100 additional worms were placed in each band cage and 30 in each soil cage. These cages were set in the open, side by side, the soil cages being sunk in the ground so that the soil surface in the cages was level with that outside. Records of the emergence of the moths were made daily, and 60 moths were secured from the two band cages and 134 from the two soil cages.

In 1921 the experiment was repeated, 100 worms having been placed in each cage in the fall of 1920. Emergence records were kept as before, 98 moths being secured from each pair of cages. In 1922 records were again obtained, 130 moths being secured from the band cages, and 57 from the soil cages.

In Table 47 the records of the emergence of moths from the bands and from the soil are compared for the three years, the dates being given on which specified percentages of the total moths had emerged. In 1920, moths emerging from the soil appeared from 6 to 13 days later than those from the bands, while in 1921 this interval was only from 1 to 4 days. In 1922 the moths emerged from the soil cages earlier than from the others, for the most part. The reduction of the interval in 1921 was due partly, if not wholly, to a period of unseasonably warm weather occurring from May 13 to June 9, and covering practically the entire emergence period of these moths. In 1922, the weather also was unseasonably warm throughout June. Thermograph records were kept both of soil and of air temperatures, and the daily mean soil temperature every year averaged from 2 to 4° higher than the air temperature.

It is evident from these experiments that, although the soil temperature averages somewhat warmer than that of the air, the emergence of moths from the soil may be somewhat delayed and may be more prolonged than that of moths from the trunks of trees. This might be even more pronounced in orchards where cover crops shade the soil.

TABLE 47.—*Emergence of moths of the spring brood of the codling moth from bands and from the soil, Yakima, Wash., 1920, 1921, 1922.*

Per cent emerged.	1920			1921			1922		
	Date emerged.		Interval.	Date emerged.		Interval.	Date emerged.		Interval.
	From bands.	From soil.		From bands.	From soil.		From bands.	From soil.	
			Days.			*Days.*			*Days.*
1	May 10	May 16	6	May 11	May 12	1	May 17	May 16	−1
10	May 15	May 26	11	May 15	May 19	4	May 22	May 18	−4
25	May 18	May 31	13	May 20	May 23	3	May 27	May 26	−1
50	May 25	June 3	9	May 24	May 26	2	May 30	May 31	1
75	May 30	June 8	9	May 29	May 30	1	June 2	June 3	1
100	June 13	June 29	16	June 6	June 6	0	June 18	June 15	−3

TIME OF DAY MOTHS EMERGE.

In order to learn at what time of the day most of the moths emerge, observations were made on moths of both the spring brood and the first brood in 1919 and 1920. Certain lots of pupæ were observed hourly from 6 a. m. to 6 p. m., inclusive, during the time the moths were emerging in quantities, and a record was kept of the number found at each observation. The records for 6 a. m. include all moths emerging between 6 p. m. and 6 a. m.

Moths of the spring brood.—In 1919, the hourly emergence of moths was observed from May 21 to June 1, inclusive, as shown in Table 48, 454 moths being recorded. The largest number for any hour emerged between 9 and 10 a. m., 27.8 per cent of the total being recorded for this hour.

TABLE 48.—*Hourly emergence of codling moths of the spring brood from 6 a. m. to 6 p. m., inclusive, Yakima, Wash., 1919.*

Date of emergence of moths.	Number of moths emerging at—													Total number of moths.
	A. M.							P. M.						
	6	7	8	9	10	11	12	1	2	3	4	5	6	
May 21	0	0	0	3	25	21	10	6	5	7	2	1	0	80
May 22	0	0	8	27	18	10	6	4	2	1	2	0	0	78
May 23	0	0	0	0	1	3	7	6	0	0	0	0	0	17
May 25	0	0	0	0	2	5	5	10	9	0	4	0	2	37
May 26	0	0	0	8	31	15	13	3	1	0	2	0	1	74
May 27	0	0	5	12	19	15	12	3	5	0	1	1	0	73
May 28	0	0	0	0	17	10	9	3	0	3	0	1	0	43
May 31	0	0	0	0	3	16	5	2	0	0	0	0	0	26
June 1	0	0	0	0	10	8	7	0	1	0	0	0	0	26
Total	0	0	13	50	126	103	74	37	23	11	11	3	3	454
Per cent	0.0	0.0	2.9	11.0	27.8	22.7	16.3	8.1	5.1	2.4	2.4	0.7	0.7	.....

In 1920, the hourly emergence of spring-brood moths was observed from May 26 to 31, inclusive, records being made of 284 moths. It will be seen in Table 49 that the largest number (32.0 per cent) emerged between 10 and 11 a. m. In both seasons a large majority of the moths emerged between 9 a. m. and noon, 66.8 per cent being recorded in 1919, and 65.5 per cent in 1920. In neither year did any moths emerge between 6 p. m. and 7 a. m.

TABLE 49.—*Hourly emergence of codling moths of the spring brood from 6 a. m. to 6 p. m., inclusive, Yakima, Wash., 1920.*

Date of emergence of moths.	Number of moths emerging at—													Total number of moths.
	A. M.							P. M.						
	6	7	8	9	10	11	12	1	2	3	4	5	6	
May 26	0	0	0	0	3	25	25	13	5	5	0	0	0	76
May 27	0	0	0	0	20	8	4	3	9	5	3	2	0	54
May 28	0	0	0	0	3	8	2	9	8	6	3	0	0	39
May 29	0	0	0	1	2	1	2	6	1	0	0	0	0	13
May 31	0	0	0	5	19	49	15	1	2	3	4	0	4	102
Total	0	0	0	6	47	91	48	32	25	19	10	2	4	284
Per cent	0.0	0.0	0.0	2.1	16.6	32.0	16.9	11.3	8.8	6.7	3.5	0.7	1.4	.....

Moths of the first brood.—Hourly emergence of first-brood moths was observed in 1919 from July 21 to 23, inclusive, 138 moths being recorded. Table 50 shows that more moths emerged between 8 and 9 a. m. than during any other hour.

TABLE 50.—*Hourly emergence of codling moths of the first brood from 6 a. m. to 6 p. m., inclusive, Yakima, Wash., 1919.*

Date of emergence of moths.	Number of moths emerging at—													Total number of moths.
	A. M.							P. M.						
	6	7	8	9	10	11	12	1	2	3	4	5	6	
July 21	1	1	14	13	9	4	4	3	3	4	2	0	1	59
July 22	1	1	0	13	13	11	2	3	5	1	0	0	0	50
July 23	4	0	0	4	0	8	5	1	6	1	0	0	0	29
Total	6	2	14	30	22	23	11	7	14	6	2	0	1	138
Per cent	4.3	1.5	10.1	21.7	15.9	16.7	8.0	5.1	10.1	4.3	1.4	0.0	0.7	.....

In 1920, observations were made from August 9 to 14, inclusive, Table 51 showing that of 234 moths the largest number emerged between 12 noon and 1 p. m. The emergence period of first-brood moths covers more hours of the day than in the case of the spring brood. In 1919, 64.4 per cent of the moths emerged between 7 a. m. and 11 a. m. In 1920, the emergence was even more prolonged, and in order to total up a comparable number of moths it is necessary to include all moths emerging between 10 a. m. and 4 p. m., between which hours 67.7 per cent of the moths emerged. In all cases, a majority of the moths emerged before the maximum temperature for the day was reached.

TABLE 51.—*Hourly emergence of codling moths of the first brood from 6 a. m. to 6 p. m., inclusive, Yakima, Wash., 1920.*

Date of emergence of moths.	Number of moths emerging at—													Total number of moths.
	A. M.							P. M.						
	6	7	8	9	10	11	12	1	2	3	4	5	6	
Aug. 9	0	0	0	1	1	2	2	11	9	4	3	0	0	33
Aug. 10	0	1	1	0	0	0	1	4	6	5	5	9	0	32
Aug. 11	2	0	0	4	1	5	2	6	0	4	1	1	0	26
Aug. 12	1	0	1	1	0	2	2	7	1	5	4	5	5	34
Aug. 13	3	0	1	2	0	6	2	11	7	6	11	4	7	60
Aug. 14	4	1	5	7	6	9	4	9	1	1	0	0	2	49
Total	10	2	8	15	8	24	13	48	24	25	24	19	14	234
Per cent	4.3	0.9	3.4	6.4	3.4	10.3	5.6	20.5	10.3	10.7	10.3	8.1	5.9	.....

TIME OF DAY MOTHS OVIPOSIT.

It is of some importance to know the time of day most of the codling moth eggs are deposited and the effect of varying degrees of temperature on egg deposition. It is particularly important to know the effect of temperature on the deposition of eggs by

the spring brood of moths, in order to time properly the first cover application of spray. These points were made the subjects of experiments in 1919 and 1920, both on moths of the spring brood and on those of the first brood, and in 1921 on moths of the first brood.

Moths of the spring brood.—In 1919, seven cages of moths, each containing approximately 25 individuals, were observed daily, beginning at 6 a. m., and observations were made every three hours, except at 3 a. m., during the period from June 3 to June 8, inclusive. The temperature at the time of making each observation was also noted. The results of these observations are given in Table 52, the number of eggs deposited in all the jars for any given period being added together. No eggs were deposited between midnight and 6 a. m., and thereafter the number increased for each period, reaching a maximum of 57.30 per cent of the total during the 3-hour period ending at 6 p. m. Between 3 p. m. and 9. p. m., 80.67 per cent of the total eggs were deposited.

TABLE 52.—*Time of oviposition by codling moths of the spring brood, in 3-hour periods, Yakima, Wash., 1919.*

Hour of observation.	Date of oviposition.												Total eggs.	Average temperature.	Per cent of eggs per 3-hour period.
	June 3		June 4		June 5		June 6		June 7		June 8				
	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.			
6 a. m.	0	*51*	0	*57*	0	*60*	0	*51*	0	*49*	0	*55*	0	*53.83*	0.00
9 a. m.	0	*63*	0	*67*	3	*68*	0	*59*	0	*61*	0	*65*	3	*63.83*	0.67
12 noon	7	*72*	0	*78*	1	*79*	1	*66*	0	*67*	0	*71*	9	*72.17*	2.02
3 p. m.	24	*76*	24	*81*	4	*79*	0	*69*	2	*71*	16	*74*	70	*75.00*	15.73
6 p. m.	119	*75*	66	*79*	41	*70*	8	*62*	9	*66*	12	*69*	255	*70.17*	57.30
9 p. m.	10	*61*	76	*66*	14	*57*	0	*52*	1	*57*	3	*54*	104	*57.83*	23.37
12 midnight	0	*58*	0	*61*	4	*56*	0	*42*	0	*51*	0	*44*	4	*52.00*	0.90
Total	160	.....	166	.....	67	.....	9	.....	12	.....	31	.....	445	.....	.....

Total number of eggs on foliage	394
Total number of eggs on cages	51
Per cent of eggs on foliage	88.54

In 1920, five cages of moths were used for observations on the time of oviposition, the results of these observations being presented in Table 53. During the time these moths were under special observation they deposited no eggs between midnight and 9 a. m. Thereafter, the number increased for each succeeding 3-hour period until the period ending 6 p. m., during which 40.92 per cent of the total were deposited. Between 3 p. m. and 9 p. m., 68.97 per cent of all eggs were deposited.

TABLE 53.—*Time of oviposition by codling moths of the spring brood, in 3-hour periods, Yakima, Wash., 1920.*

Hours of observation.	Date of oviposition.												Total eggs.	Average temperature.	Per cent of eggs per 3-hour period.
	June 19		June 20		June 21		June 25		June 26		June 27				
	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.			
6 a. m.	0	58	0	58	0	60	0	54	0	52	0	61	0	57.17	0.00
9 a. m.	0	68	0	69	0	74	0	64	0	66	0	75	0	69.33	0.00
12 noon	2	78	0	79	0	89	8	69	10	75	0	78	20	78.00	6.60
3 p. m.	2	80	13	79	1	92	15	67	31	78	6	82	68	79.67	22.44
6 p. m.	28	77	26	73	10	81	5	61	24	78	31	81	124	75.17	40.92
9 p. m.	66	64	1	61	5	70	0	51	4	65	9	71	85	63.67	28.05
12 midnight	5	60	0	50	0	64	0	50	1	63	0	65	6	58.67	1.98
Total	103		40		16		28		70		46		303		

Total number of eggs on foliage 246
Total number of eggs on cages 57
Per cent of eggs on foliage 81.19

These tables demonstrate that the spring brood of moths deposit a great majority of their eggs between 3 p. m. and 9 p. m. A comparison of the temperatures with the number of eggs deposited shows that very few eggs are deposited when the temperature is below 60° F. For example, in Table 53, no eggs were deposited on June 25 between 6 p. m. and 9 p. m., the temperature being 61° F. at 6 p. m. and 51° F. at 9 p. m. On the other hand, high temperatures do not necessarily cause the moths to oviposit, the maximum oviposition occurring nearly always after the maximum temperature for the day has been reached.

Moths of the first brood.—In 1919, six cages of moths were used for 3-hour oviposition records, the data secured from this study being shown in Table 54. The maximum oviposition occurred between 3 p. m. and 6 p. m., 41.20 per cent of the eggs being laid during this time, and between noon and 6 p. m., 79.27 per cent of the eggs were deposited. With one exception, no eggs were deposited between midnight and 9 a. m.

TABLE 54.—*Time of oviposition by codling moths of the first brood, in 3-hour periods, Yakima, Wash., 1919.*

Hour of observation.	Date of oviposition.												Total eggs.	Average temperature.	Per cent of eggs per 3-hour period.
	July 31		Aug. 1		Aug. 2		Aug. 3		Aug. 4		Aug. 5		Aug. 6				
	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.			
6 a. m.	0	64	1	57	0	60	0	59	0	55	0	56	0	62	1	59.00	0.05
9 a. m.	0	73	0	66	0	69	0	68	0	67	0	71	0	74	0	69.71	0.00
12 noon	0	83	2	78	0	78	26	76	0	73	5	79	0	88	33	79.29	1.61
3 p. m.	90	88	404	83	47	81	100	74	104	73	34	83	0	91	779	81.86	38.07
6 p. m.	341	72	170	77	89	79	69	65	54	69	94	81	26	90	843	76.14	41.20
9 p. m.	36	64	30	65	48	65	6	63	1	62	89	69	157	77	367	66.45	17.94
12 mt.	4	62	0	62	1	63	0	60	0	59	3	67	15	74	23	63.86	1.12
Total	471		607		185		201		159		225		198		2,046		

Total number of eggs on foliage 1,382
Total number of eggs on cages 664
Per cent of eggs on foliage 67.55

In 1920, five cages of moths were used and, as shown in Table 55, the majority of the eggs, 54.18 per cent, were deposited between 6 p. m. and 9 p. m., and 88.47 per cent were deposited between 3 p. m. and 9 p. m.

TABLE 55.—*Time of oviposition by codling moths of the first brood, in 3-hour periods, Yakima, Wash., 1920.*

Hour of observation.	Date of oviposition.												Total eggs.	Average temperature.	Per cent of eggs per 3-hour period.
	Aug. 9		Aug. 10		Aug. 11		Aug. 12		Aug. 13		Aug. 14				
	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.			
6 a. m.	0	70	0	64	0	63	0	68	0	69	0	71	0	67.50	0.00
9 a. m.	0	77	0	81	0	80	0	79	0	81	2	82	2	80.00	0.21
12 noon	0	80	2	93	0	90	6	92	12	95	4	94	24	90.67	2.54
3 p. m.	20	80	8	94	3	91	4	95	0	99	2	99	37	93.00	3.92
6 p. m.	51	82	101	87	75	85	23	87	35	85	39	86	324	85.33	34.29
9 p. m.	86	71	132	76	57	68	82	71	119	81	36	82	512	74.83	54.18
12 mt.	0	73	12	75	3	72	1	65	19	80	11	77	46	73.67	4.87
Total	157	.....	255	.....	138	.....	116	.....	185	.....	94	.....	945	.....	.....

Total number of eggs on foliage 676
Total number of eggs on cages 269
Per cent of eggs on foliage 71.53

In 1921, this study was again made with first-brood moths, five cages being used. As in 1920, the majority of the eggs, 54.68 per cent, were deposited between 6 p. m. and 9 p. m., and 89.35 per cent were deposited between 3 p. m. and 9 p. m. (See Table 56.)

TABLE 56.—*Time of oviposition by codling moths of the first brood, in 3-hour periods, Yakima, Wash., 1921.*

Hour of observation.	Date of oviposition.								Total eggs.	Average temperature	Per cent of eggs per 3-hour period.
	Aug. 2		Aug. 3		Aug. 4		Aug. 5				
	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.			
6 a. m.	0	68	0	60	0	60	0	56	0	61.00	0.00
9 a. m.	0	77	0	71	0	69	0	70	0	71.75	0.00
12 noon	0	86	0	80	8	80	11	82	19	82.00	1.29
3 p. m.	0	88	13	82	78	82	3	86	94	84.50	6.38
6 p. m.	199	79	67	77	210	80	35	85	511	80.25	34.67
9 p. m.	310	70	47	65	174	67	275	71	806	68.25	54.68
12 mt.	1	65	2	61	0	61	41	69	44	64.00	2.98
Total	510	.....	129	.....	470	.....	365	.....	1,474	.....	.....

Total number of eggs on foliage 776
Total number of eggs on cages 698
Per cent of eggs on foliage 52.65

These tables show that normally the first brood of moths deposit most of their eggs between 3 p. m. and 9 p. m., just as is the case with the spring brood of moths. It will be noted, however, that within this 6-hour period first-brood moths deposit more eggs after 6 p. m. than before, while the reverse is true of the spring brood. This is probably due to the fact that evening temperatures in August are higher than those in June. The first brood of moths of 1919 were an exception to this apparent rule, depositing more eggs between noon and 3 p. m. than between 6 p. m. and 9 p. m., and the maximum number being found at 6 p. m. instead of at 9 p. m. During the period of observation in 1919 the weather was cooler than usual, and quite windy, at least during the latter part of nearly every day. This possibly caused the moths to oviposit earlier than they would during the normal, hot, nearly windless weather which obtained at the time observations were made in 1920 and 1921.

OVIPOSITION BY INDIVIDUAL MOTHS.

In order to ascertain the number of eggs deposited by individual female codling moths, freshly emerged moths were paired and each pair placed in a cloth-covered jelly glass, containing moist sand, a sponge saturated in brown sugar solution, and fresh pear leaves, as in the other oviposition experiments. These cages were examined daily, the number of eggs recorded, and fresh leaves and sugar solution supplied.

TABLE 57.—*Oviposition by individual codling moths of the spring brood, Yakima, Wash., 1919.*

Pair No.	Emergence of moths.	Date of—			Number of days—			Length of life of female after oviposition.	Total length of life of female moth.	Number of days on which oviposition occurred.	Total number of eggs.	Average number of eggs per oviposition.	Maximum number of eggs deposited in one day.
		First oviposition.	Last oviposition.	Death of female moth.	Before oviposition.	Of oviposition.	From emergence to last oviposition.						
								Days.	*Days.*				
1	May 20	.....	.....	June 3	.....	.....	.....	.....	14	.....	0	.....	.....
2	...do.....	May 24	May 24	June 7	4	1	4	14	18	1	1	1.0	1
3	May 21	May 31	June 21	June 23	10	22	31	2	33	10	86	8.6	38
4	...do.....	.....	.....	June 21	.....	.....	.....	.....	31	.....	0	.....	.....
5	...do.....	.....	.....	June 9	.....	.....	.....	.....	19	.....	0	.....	.....
6	...do.....	May 24	June 2	June 4	3	10	12	2	14	2	4	2.0	3
7	...do.....	.....	.....	June 6	.....	.....	.....	.....	16	.....	0	.....	.....
8	May 22	.....	.....	June 8	.....	.....	.....	.....	17	.....	0	.....	.....
9	...do.....	.....	.....	May 25	.....	.....	.....	.....	3	.....	0	.....	.....
10	May 24	.....	.....	June 4	.....	.....	.....	.....	11	.....	0	.....	.....
11	...do.....	June 4	June 11	June 12	11	8	18	1	19	5	13	2.6	7
12	...do.....	.....	.....	June 5	.....	.....	.....	.....	12	.....	0	.....	.....
13	...do.....	.....	.....	...do.....	.....	.....	.....	.....	12	.....	0	.....	.....
14	...do.....	June 1	June 7	June 10	8	7	14	3	17	4	13	3.3	4
15	...do.....	May 31	June 14	(1)	7	15	21	.....	.....	8	26	3.3	8
16	...do.....	June 2	June 7	June 14	9	6	14	7	21	5	26	5.2	11
17	May 25	...do.....	June 2	June 6	8	1	8	4	12	1	1	1.0	1
18	...do.....	.....	.....	June 8	.....	.....	.....	.....	14	.....	0	.....	.....
19	...do.....	June 13	June 13	June 14	19	1	19	1	20	1	3	3.0	3
20	...do.....	.....	.....	June 2	.....	.....	.....	.....	8	.....	0	.....	.....
21	...do.....	.....	.....	June 10	.....	.....	.....	.....	16	.....	0	.....	.....
					.....	.....	.....	.....	.....	37	173	.....	.....

[1] Date of death unknown.

TABLE 57.—*Oviposition by individual codling moths of the spring brood, Yakima, Wash., 1919*—Continued.

SUMMARY.

	Average.	Maximum.	Minimum.
Number of days before oviposition	8.78	19	3
Number of days from emergence to last oviposition	15.67	31	4
Number of days of oviposition	7.89	22	1
Number of days on which oviposition occurred	4.11	10	1
Number of days female moth lived after last oviposition	4.25	14	1
Total length of life of female moth in days	16.35	33	3
Number of eggs deposited by one female moth	8.24	86	0
Number of eggs deposited by one female moth in one day	4.68	38	0

Moths of the spring brood, 1919.—Twenty-one pairs of spring-brood moths were segregated in 1919, and the results are given in Table 57. The average length of life of the females was 16.35 days, as compared with 16.91 for females confined in battery-jar cages (see Table 4). The average number of eggs per female in the individual jars was 8.24, while 300 females in the larger cages averaged only 6.36 eggs (see Table 3). The periods in the life of the moths in this table are not comparable with those of Table 3, which gives the data for all moths in each cage rather than for each individual moth. The largest number of eggs deposited by a female in one day was 38 and during her life 86.

No satisfactory oviposition records for individual moths were obtained in 1920.

Moths of the spring brood, 1921.—In 1921, six pairs of spring-brood moths were segregated on May 29 and May 31 each, as shown in Table 58. A comparison with Table 35 will show the average length of life of 723 females confined in battery jar cages to be 13.85 days, while the average life of 12 females confined in pairs was 14.75 days. These females laid 288 eggs, an average of 24. The female of pair No. 2 deposited 94 eggs, 47 of them being the maximum daily oviposition for a single female. The average egg deposition for the two years was 13.97 eggs per female.

TABLE 58.—*Oviposition by individual codling moths of the spring brood, Yakima, Wash., 1921.*

Pair No.	Emergence of moths.	Date of—			Number of days—			Length of life of female after oviposition.	Total length of life of female moth.	Number of days on which oviposition occurred.	Total number of eggs.	Average number of eggs per oviposition.	Maximum number of eggs deposited in one day.
		First oviposition.	Last oviposition.	Death of female moth.	Before oviposition.	Of oviposition.	From emergence to last oviposition.						
								Days.	*Days.*				
1	May 29	June 5	June 17	June 23	7	13	19	6	25	7	19	2.7	7
2	...do....	June 1	June 9	June 16	3	9	11	7	18	8	94	11.8	47
3	...do....	May 31	...do....	June 14	2	10	11	5	16	8	89	11.1	44
4	...do....	June 2	June 11	June 12	4	10	13	1	14	9	55	6.1	15
5	...do....	June 7	June 22	June 23	9	16	24	1	25	3	10	3.3	7
6	...do....	June 3	June 3	June 11	5	1	5	8	13	1	1	1.0	1
7	May 31	June 6	June 6	...do....	6	1	6	5	11	1	1	1.0	1
8	...do....	June 8	June 8	June 10	8	1	8	2	10	1	1	1.0	1
9	...do....	.....	.....	June 9	.....	.....	.....	.....	9	.....	0	.....	.....
10	...do....	June 4	June 8	June 12	4	5	8	4	12	2	3	1.5	2
11	...do....	.....	.....	June 7	.....	.....	.....	.....	7	.....	0	.....	.....
12	...do....	June 3	June 8	June 17	3	6	8	9	17	5	15	3.0	6
					.....	.....	.....	.....	.....	45	288	.....	.....

TABLE 58.—*Oviposition by individual codling moth of the spring brood, Yakima, Wash., 1921*—Continued.

SUMMARY.

	Average.	Maximum.	Minimum.
Number of days before oviposition	5.10	9	2
Number of days from emergence to last oviposition	11.30	24	5
Number of days of oviposition	7.20	16	1
Number of days on which oviposition occurred	4.50	9	1
Number of days female moth lived after last oviposition	4.80	9	1
Total length of life of female moth in days	14.75	25	7
Number of eggs deposited by one female moth	24.00	94	0
Number of eggs deposited by one female moth in one day	6.40	47	0

Moths of the first brood, 1919.—Of the 33 female moths of the first brood segregated in pairs in jelly-glass cages in 1919, 8 of them failed to deposit eggs as shown in Table 59. However, the remaining 25 laid 988 eggs, or an average of 29.94 eggs for the 33 females. The average number of eggs per female in Table 10 is 23.39. The average length of life of the 33 females in the individual cages was 15.24 days, which is 2.15 days longer than the average found in Table 11. Table 59 also shows the maximum number of eggs per female to be 173, which is the largest number accurately recorded in these studies.

TABLE 59.—*Oviposition by individual codling moths of the first brood, Yakima, Wash., 1919.*

Pair No.	Emergence of moths.	Date of—			Number of days—			Length of life of female after oviposition.	Total length of life of female moth.	Number of days on which oviposition occurred.	Total number of eggs.	Average number of eggs per oviposition.	Maximum number of eggs deposited in one day.
		First oviposition.	Last oviposition.	Death of female moth.	Before oviposition.	Of oviposition.	From emergence to last oviposition.						
								Days.	*Days.*				
1	July 23	.....	.....	Aug. 2	.....	.....	.....	.....	10	.....	0	.....	.....
2	...do.....	July 25	Aug. 7	Aug. 8	2	14	15	1	16	11	91	8.3	18
3	...do.....	Aug. 2	Aug. 6	Aug. 6	10	5	14	0	14	3	13	4.3	5
4	...do.....	July 25	Aug. 2	Aug. 3	2	9	10	1	11	7	18	2.6	4
5	...do.....	...do.....	Aug. 6	Aug. 7	2	13	14	1	15	8	25	3.1	8
6	...do.....	Aug. 6	Aug. 10	Aug. 11	14	5	18	1	19	5	36	7.2	28
7	July 25	...do.....	Aug. 6	Aug. 7	12	1	12	1	13	1	1	1.0	1
8	...do.....	July 27	...do.....	...do.....	2	11	12	1	13	2	3	1.5	2
9	...do.....	July 30	Aug. 9	Aug. 11	5	11	15	2	17	3	14	4.7	8
10	...do.....	Aug. 5	Aug. 12	Aug. 13	11	8	18	1	19	3	5	1.7	2
11	July 27	.....	.....	Aug. 6	.....	.....	.....	.....	10	.....	0	.....	.....
12	...do.....	July 31	Aug. 9	Aug. 13	4	10	13	4	17	3	14	4.7	12
13	...do.....	.....	.....	Aug. 10	.....	.....	.....	.....	14	.....	0	.....	.....
14	...do.....	.....	.....	Aug. 12	.....	.....	.....	.....	16	.....	0	.....	.....
15	...do.....	July 30	Aug. 14	Aug. 22	3	16	18	8	26	9	29	3.2	7
16	...do.....	July 29	Aug. 4	Aug. 6	2	7	8	2	10	3	5	1.7	3
17	July 28	.....	.....	Aug. 7	.....	.....	.....	.....	10	.....	0	.....	.....
18	...do.....	July 29	Aug. 5	Aug. 6	1	8	8	1	9	8	102	12.8	31
19	...do.....	Aug. 1	Aug. 10	Aug. 12	4	10	13	2	15	6	107	17.8	44
20	...do.....	July 29	July 29	...do.....	1	1	1	14	15	1	1	1.0	1
21	...do.....	...do.....	Aug. 11	...do.....	1	14	14	1	15	6	22	3.7	15
22	...do.....	July 30	July 31	Aug. 10	2	2	3	10	13	2	82	41.0	78
23	July 29	Aug. 1	Aug. 8	Aug. 18	3	8	10	10	20	3	16	5.3	12
24	...do.....	.....	.....	Aug. 6	.....	.....	.....	.....	8	.....	0	.....	.....
25	...do.....	July 30	Aug. 13	Aug. 15	1	15	15	2	17	7	81	11.6	24
26	...do.....	...do.....	Aug. 8	Aug. 17	1	10	10	9	19	3	4	1.3	2
27	...do.....	Aug. 11	Aug. 16	Aug. 16	13	6	18	0	18	2	4	2.0	3
28	...do.....	July 30	Aug. 6	Aug. 17	1	8	8	11	19	8	133	16.6	38
29	Aug. 3	Aug. 8	Aug. 15	Aug. 18	5	8	12	3	15	3	6	2.0	3
30	...do.....	.....	.....	Aug. 22	.....	.....	.....	.....	19	.....	0	.....	.....
31	...do.....	Aug. 22	Aug. 24	Aug. 30	19	3	21	6	27	2	3	1.5	2
32	...do.....	Aug. 7	Aug. 16	Aug. 17	4	10	13	1	14	9	173	19.2	71
33	...do.....	.....	.....	Aug. 13	.....	.....	.....	.....	10	.....	0	.....	.....
					.....	.....	.....	.....	.....	118	988	.....	.....

TABLE 59.—*Oviposition by individual codling moths of the first brood, Yakima, Wash., 1919*—Continued.

SUMMARY.

	Average.	Maximum.	Minimum.
Number of days before oviposition	5.00	19	1
Number of days from emergence to last oviposition	12.52	21	1
Number of days of oviposition	8.52	16	1
Number of days on which oviposition occurred	4.72	11	1
Number of days female moth lived after last oviposition	4.04	14	0
Total length of life of female moth in days	15.24	27	8
Number of eggs deposited by one female moth	29.94	173	0
Number of eggs deposited by one female moth in one day	8.37	78	0

HATCHING OF THE EGG.

When the larva is ready to leave the egg it moves its head back and forth as if to stretch the eggshell. The mandibles are moved about rapidly until the point of one of them is forced through the chorion, always at some place on the periphery of the egg. An opening the size of the head is soon made in the eggshell and the larva crawls quickly out. Occasionally, a larva has been observed to kill itself in an effort to emerge from the egg by projecting the anal end first through a hole smaller than its head.

DATE OF HATCHING OF LARVÆ.

Since the time when the first, the last, and the maximum number of larvæ of each brood of the codling moth hatch and enter the fruit is the most important phase of the life-history studies in their practical application to control measures, a comparative diagram of the hatching during 1919, 1920, and 1921 is given in Figure 35. It will be noticed that the hatching curves for the first brood are entirely unlike, and that the first larvæ in 1919 hatched 5 days later than the first larvæ in 1921, and the first in 1920, 6 days later than the first in 1919. The maximum hatching in 1921 occurred only 7 days after the first hatching, and this was 10 days earlier than the date of maximum hatching in 1919, and 20 days before that of 1920.

The hatching curves of the second brood are much more alike than those of the first brood, and the dates of the first and maximum hatching are nearly the same. It will be noticed that the dates of the first hatching in 1919 and 1921 are identical, and that for 1920 is 11 days later. The date of maximum hatching in 1920 is also identical with that in 1921, in spite of the difference of 11 days in the date of hatching of the first larvæ, and the date of maximum hatching of second-brood larvæ in 1919 is but 5 days earlier. Figure 35 shows the necessity of accurate life-history data wherever efficient and economical control is to be obtained.

HABITS OF NEWLY-HATCHED LARVÆ.

Directly upon emerging from the egg the young larvæ seek food, which in the case of the codling moth is preferably the fruit of the apple or pear. Occasionally they will burrow into the veins and stems of leaves, and even into the terminal twigs (as shown in Pl. III, fig. 1). However, of about 250 newly-hatched larvæ which

were placed on the terminal twigs of a small apple tree, only two developed to half their normal size before they died.

Before attacking the fruit, the larva will crawl about for several minutes seeking a suitable place to enter. It prefers the calyx cup, stem cavity, or an injury to the skin, as these places afford protection and ease of entrance. When beginning to feed, the larva removes the pubescence on the surface of the apple and cuts into the skin, using its mandibles with a circular motion of the head similar to the action of an auger. The greater part of the skin which is cut away is piled beside the hole, though a little is eaten. Larvæ entering apples dipped in a red stain showed the stained particles very clearly in their digestive systems soon after feeding began. When a hole the size of the head is cut through the skin,

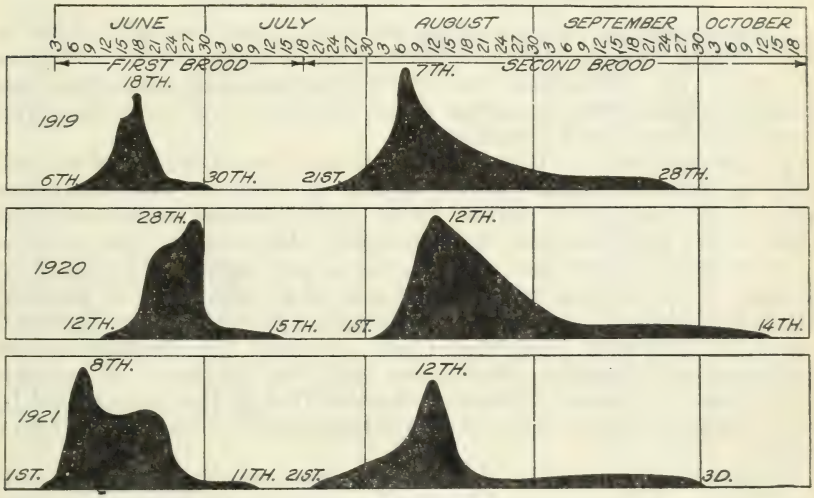


FIG. 35.—Time of hatching of codling moth larvæ, Yakima, Wash.

the larva excavates a cell large enough to contain its body, and enters, at the same time pulling over the entrance of the burrow the frass which it has laid aside and held in place with silk. This process requires about 1½ hours.

PERCENTAGE OF TRANSFORMING AND WINTERING LARVÆ.

In Table 60, it is shown that 84.97 per cent of the first brood of larvæ transformed the same season in 1919, 76.80 per cent in 1920, and 82.78 per cent in 1921. In both 1919 and 1921, 6 larvæ of the second brood transformed the same year, being 1.42 per cent and 1.02 per cent, respectively, of the total larvæ, while in 1920 only one second-brood larva, 0.21 per cent of the total, transformed. In 1919, 15.03 per cent of the first brood of larvæ did not transform until the following spring, in 1920 the percentage was 23.20, and in 1921 it was 17.22. Practically all of the second brood of larvæ pass the winter in cocoons, the percentages being 98.58 in 1919, 99.79 in 1920, and 98.98 in 1921.

TABLE 60.—*Percentage of transforming and wintering codling moth larvæ, Yakima, Wash., 1919, 1920, and 1921.*

Year.	Brood.	Number of larvæ—			Per cent transforming.	Per cent wintering.
		Leaving fruit.	Transforming.	Wintering.		
1919	First	173	147	26	84.97	15.03
	Second	423	6	417	1.42	98.58
1920	First	306	235	71	76.80	23.20
	Second	485	1	484	.21	99.79
1921	First	662	548	114	82.78	17.22
	Second	589	6	583	1.02	98.98

NATURAL ENEMIES OF THE CODLING MOTH.

Natural enemies of the codling moth are conspicuously absent in the Yakima Valley. While collecting larvæ from bands, evidences of attack by predacious insects were occasionally observed, and carabid beetles were numerous about the trees, but no beetles were noticed in the act of killing larvæ.

In October, 1919, at Buena, Wash., a small number of codling-moth eggs on harvested apples were found to be infested with a parasite, which upon emergence proved to be *Trichogramma minutum* Riley. This is the only instance of parasitism observed in these studies.

In 1914, at Wenatchee, Wash., the senior author collected from cocoons of the codling moth a specimen of an ichneumonid parasite, which was determined by R. A. Cushman, of the Bureau of Entomology, to be *Aenoplex plesiotypus* Cush. In 1916, at Wenatchee, two specimens of *Aenoplex plesiotypus* and one specimen of another ichneumonid parasite, *Epiurus indagator* Walsh, also determined by R. A. Cushman, were reared from codling-moth cocoons by the senior author.

Because of the absence of natural enemies of the codling moth in the Yakima Valley, several hundred codling-moth larvæ parasitized by *Ascogaster carpocapsae* Vier. and *Bassus carpocapsae* Cush. were sent to this laboratory from Dover, Del., by E. R. Selkregg, from Cornelia, Ga., by E. R. Van Leeuwen, and from Sandusky, Ohio, by G. A. Runner, all of the Bureau of Entomology. Many of these succumbed during the extreme cold of December, 1919, and no results were obtained the following year. In 1921 a large number of these parasites were reared and liberated, and evidences of parasitism were observed in several codling-moth larvæ collected under bands in August and September. In June, 1922, two specimens of *Bassus carpocapsae* were reared from this material, showing that this species is becoming established. These attempts to introduce hymenopterous parasites of the codling moth will be continued.

REVIEW OF SEASONAL HISTORY OF THE CODLING MOTH IN 1919, 1920, AND 1921.

The seasonal history of the codling moth in the Yakima Valley for 1919, 1920, and 1921 is given graphically in Figures 11, 22, and 32. Each curve shows approximately the occurrence of one stage in the development of the insect. A comparison of the seasonal history for the three seasons is given in Table 61.

TABLE 61.—*Comparison of seasonal history of the codling moth, Yakima, Wash., 1919, 1920, and 1921.*

Stage and year.	Date of—		
	First.	Maximum.	Last.
Pupation of spring brood:			
1919	Apr. 8	Apr. 27	May 26
1920	Apr. 3	Apr. 26	May 17
1921	Apr. 9	Apr. 17	June 6
Emergence of spring-brood moths:			
1919	May 13	May 21	June 19
1920	May 10	June 2	July 2
1921	May 19	May 30	June 27
Deposition of first-brood eggs:			
1919	May 21	June 4	June 24
1920	May 12	June 18	July 11
1921	May 23	June 4	June 30
Hatching of first-brood eggs:			
1919	June 7	June 18	June 29
1920	June 12	June 28	July 14
1921	June 2	June 8	July 10
First-brood larvæ leaving fruit:			
1919	June 23	July 12	July 31
1920	July 6	July 18	Aug. 16
1921	June 22	July 14	Aug. 3
Pupation of first-brood larvæ:			
1919	July 7	July 19	Aug. 12
1920	July 10	July 17	Aug. 15
1921	July 5	July 23	Aug. 15
Emergence of first-brood moths:			
1919	July 8	July 19	Sept. 24
1920	July 23	Aug. 15	Sept. 30
1921	July 13	July 31	Oct. 9
Deposition of second-brood eggs:			
1919	July 15	July 29	Sept. 20
1920	July 27	Aug. 7	Oct. 10
1921	July 15	Aug. 7	Oct. 13
Hatching of second-brood eggs:			
1919	July 22	Aug. 7	Sept. 27
1920	Aug. 2	Aug. 12	Oct. 13
1921	July 22	Aug. 12	Oct. 2
Second-brood larvæ leaving fruit:			
1919	Aug. 13	Sept. 3	Oct. 28
1920	Aug. 19	Sept. 4	Nov. 2
1921	Aug. 10	Sept. 5	Nov. 13

SUMMARY.

The seasonal-history studies recorded in this bulletin were made in the Yakima Valley of Washington during the years 1919, 1920, and 1921.

The codling moth, while not as serious a pest in Washington as it is in some other States, is the most serious and widespread insect pest with which the Washington apple growers have to deal. The climatic conditions are such that two practically complete generations occur, with a very small third generation in some seasons, as evidenced by the data herein.

A comparative summary of the length of the various periods in the life cycle of the codling moth at Yakima in 1919, 1920, and 1921, is given in Table 62. The figures in this table are taken from the individual tables and not from the combined life-cycle tables for each year.

TABLE 62.—*Summary of the average length of the different periods in the life cycle of the codling moth, Yakima, Wash., 1919, 1920, 1921.*

Season.	Spring brood.		First generation.						Second generation.				
	Pupal period.	Preoviposition period.	Incubation period.	Feeding period.[1]	Cocooning period.	Pupal period.	Preoviposition period.	Life cycle.	Incubation period.	Feeding period (transforming larvæ).[1]	Cocooning period.	Pupal period.	Feeding period (wintering larvæ).[1]
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
1919	31.63	5.53	12.73	23.82	6.99	13.91	1.63	58.42	8.72	21.80	7.20	16.00	34.51
1920	33.56	6.87	10.60	19.05	5.48	12.37	2.93	48.01	8.74				35.30
1921	29.53	2.47	9.31	25.83	6.12	12.62	1.74	55.88	7.70	16.60	2.50	17.67	34.02
Grand average	31.57	4.96	10.88	22.90	6.20	12.97	2.10	54.10	8.39	19.20	4.85	16.84	34.61

[1] Stock-jar method.

The various phases in the life of the adult codling moths for the three seasons are compared in Table 63.

TABLE 63.—*Summary of the phases in the life of the adult codling moth, Yakima, Wash., 1919–1921.*

Phase and year.	Minimum.	Average.	Maximum.
Number of days before oviposition by spring-brood moths:			
1919	1	5.53	18
1920	1	6.83	22
1921	1	2.47	18
Number of days before maximum oviposition by spring-brood moths:			
1919	3	9.93	18
1920	3	12.45	23
1921	2	5.53	18
Number of days of oviposition by spring-brood moths:			
1919	2	14.67	24
1920	1	15.03	27
1921	9	19.11	27
Number of days from emergence to last oviposition by spring-brood moths:			
1919	8	19.20	28
1920	9	20.70	34
1921	11	20.58	27
Number of eggs per female moth of the spring brood:			
1919	1	6.36	86
1920		6.71	
1921	1	19.77	94
Length of life of male moths of the spring brood:			
1919	1	15.33	28
1920	2	16.65	43
1921	2	12.29	33
Length of life of female moths of the spring brood:			
1919	2	16.91	29
1920	2	17.73	45
1921	2	13.85	35
Number of days before oviposition by first-brood moths:			
1919	1	1.63	4
1920	1	2.93	14
1921	1	1.74	7
Number of days before maximum oviposition by first-brood moths:			
1919	1	4.21	14
1920	1	5.55	18
1921	2	3.79	9
Number of days of oviposition by first-brood moths:			
1919	9	14.95	24
1920	5	15.70	26
1921	1	13.56	29
Number of days from emergence to last oviposition by first-brood moths:			
1919	9	15.58	26
1920	9	17.64	29
1921	7	14.29	29

TABLE 63.—*Summary of the phases in the life of the adult codling moth, Yakima, Wash., 1919–1921*—Continued.

Phase and year.	Minimum.	Average.	Maximum.
Number of eggs per female moth of the first brood:			
1919	1	23.39	173
1920		21.96	
1921		20.39	
Length of life of male moths of the first brood:			
1919	2	13.97	45
1920	2	13.87	34
1921	1	11.72	39
Length of life of female moths of the first brood:			
1919	1	13.08	37
1920	1	13.24	40
1921	1	11.39	50

Studies of certain phases of the seasonal history of the codling moth in the upper and lower Yakima Valleys indicate that the spring brood of moths appears in both valleys at about the same time, but that the majority of the mature larvæ of the first brood are leaving the apples from a week to two weeks earlier in the lower valley.

Incomplete seasonal history data recorded at Wenatchee, Wash., in 1915 and 1916 indicate that the life cycle of the codling moth is approximately the same at Wenatchee as at Yakima.

A winter temperature of −25° F. or colder may kill all the codling moth larvæ above snow line, a temperature of −20° to −25° F. may kill 80 to 90 per cent of the larvæ, a temperature of −15° to −20° F. may kill 70 to 80 per cent, while a temperature of only −7° or −8° F. kills only about 4 per cent of the wintering larvæ.

Moths of the spring brood emerging from cocoons spun in the soil may appear from 1 to 9 days later than those from cocoons above ground, although in 1922 they appeared earlier on the average.

Most of the moths of the spring brood emerge in the morning, two-thirds of them appearing between 9 a. m. and noon. Moths of the first brood emerge over a longer period of the day, but the majority of them appear before the maximum temperature for the day is reached.

Female moths of the spring brood deposit 65 to 80 per cent of their eggs between the hours of 3 p. m. and 9 p. m., most of these being deposited before 6 p. m. Very few eggs are deposited unless the temperature is 60° F. or higher. Female moths of the first brood also deposit a great majority of their eggs between 3 p. m. and 9 p. m., but owing to the higher temperatures most of these eggs are deposited after 6 p. m.

From oviposition records obtained from individual female moths of the spring brood it appears that the moths may lay as many as 94 eggs, while others will lay none, the average being 14. Moths of the first brood deposit twice as many eggs, the number ranging from none to 173, with an average of 30.

The codling moth larva emerges from the egg through an opening made in the periphery, never through the portion of the eggshell adhering to the fruit or leaf.

The date of hatching of the earliest larvæ of the first brood varied as much as 11 days in the three years the codling moth was under

observation in the Yakima Valley, and the date of maximum hatching varied 20 days. The date of earliest hatching of the second brood of larvæ also varied 11 days, while the date of maximum hatching varied only 5 days.

Newly hatched larvæ, after finding an apple or pear, will crawl about over it for some time before entering it. It requires an hour or more for the larva to hide itself in the fruit, and most of the skin is bitten off in small pieces and not eaten. If a larva fails to find a fruit, it may burrow into the midrib of a leaf or a terminal shoot, but it appears to be unable to maintain itself on this food.

From 75 to 85 per cent of the first brood of larvæ, and from less than 1 per cent to nearly 2 per cent of the second brood of larvæ transform the same season, the others waiting until the following year.

The egg parasite *Trichogramma minutum* Riley has been observed in the Yakima Valley, and the larval parasites *Aenoplex plesiotypus* Cush. and *Epiurus indagator* Walsh were observed at Wenatchee. Occasional evidence of predators was observed.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

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77

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